



GEO-Academy: Innovative digital GEO-Tools for enhancing teachers' digital, green and spatial skills towards an effective STEAM Education for Sustainable Development

D4.3: GEO-KITS

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Executive Summary

Deliverable 4.3 (D4.3) presents the GEO-Kit, a low-cost, modular hardware kit developed under Task 4.4 of Work Package 4 (WP4), as a key enabler of the GEO-Labs activities. It was designed for teachers without a background in electronics or programming, while remaining extensible for more advanced classrooms. The same components are reused across six inquiry-based activities, namely, building a Micro:bit seismometer, investigating air quality, a cartography and GIS "Peddy Paper", map storytelling through sonification, agro-climatic monitoring, and smart lighting, which together cover all five GEO-Concepts and the project's unified competence framework.

The GEO-Kit was refined iteratively through use in training events and pilot classrooms across all consortium countries. It featured in the three International Training Events (Marathon 2024, Vienna 2025 and Sesimbra 2025) and the local and national training activities delivered through the seven national hubs. Direct classroom implementations were documented in all consortium countries, spanning primary to upper-secondary levels and a range of subjects. All GEO-Kit materials have been published on the GEOOBSERVE platform, so that teachers across Europe can download, adapt, translate and reuse them. Thus, D4.3 sets out how these resources have been organised, promoted through the national hubs, training events and project communication channels, and will be sustained beyond the project's end.

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1 Introduction

1.1 Project overview

GEO-Academy is an Erasmus+ project implemented by a consortium of 12 partners from 7 EU countries. Over a period of 36 months beginning in June 2023, GEO-Academy has established a network of teachers and teacher trainers and developed training resources as well as an international community advocating to enhance STEAM education through the inclusion of Geographic Information Systems (GIS), Cartography, Remote Sensing (RS) and Earth Observation (EO), as well as robotics and coding in Education for Sustainable Development (ESD). By targeting both pre- and in-service teachers, GEO-Academy has enhanced educators' digital competencies, green skills, and spatial skills, enabling them to incorporate inspiring examples of environmental and climate phenomena using real world data through digital storytelling across a range of subject domains.

GEO-Academy accomplished this by focusing on 5 GEO-Concepts¹ as the foundations of the project's substantive ambition, and from these developing educational models for teacher training structured along the three competency pillars (Digital, Green, and Spatial). Initial training courses through national training GEO-Hubs were then evaluated, improved, and disseminated through the GEOBSERVE platform, a repository and community of practice developed by the project for sharing resources and best practices. The next stage involved scaling up training activities through local, national, and international events, from seminars to summer schools to conferences, and more. The result has been an expanding network of teachers and teacher trainers at the institute-level (GEO-Labs) empowered with access to new and innovative teaching tools acting as social innovators and community leaders and ambassadors in climate change education, with resources accessible beyond the project's physical and temporal boundaries.

¹ The five GEO-Concepts are: (1) Cartography and spatial thinking; (2) GIS tools and techniques; (3) Remote Sensing, Earth Observation and satellite applications; (4) Map storytelling; (5) STEAM education, robotics and coding.

2 The GEO-Labs and GEO-Kits Concept

2.1 Rationale: GEO-Labs as Living Labs in Schools

The GEO-Labs concept was introduced and elaborated in Deliverable 2.2 of the project (D2.2: Pedagogical model for the GEO-Academy teacher education and professional development). GEO-Labs are conceived as Geospatial Living Labs hosted within schools, where students, teachers, researchers and local stakeholders co-create solutions to authentic sustainability challenges using geospatial technologies. The Living Lab (LL) methodology is issue-driven and rooted in transdisciplinary work; it cycles through co-creation, rapid prototyping, experimentation and evaluation, with school communities as the central players. Within a GEO-Lab, this cycle is supported by the digital tools and resources curated on the GEOOBSERVE platform and by the physical tools provided through the GEO-Kit.

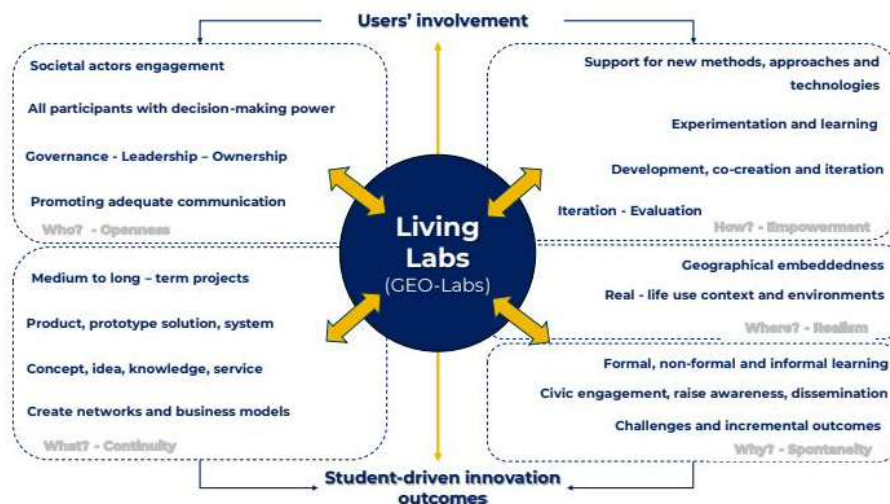


Figure 1: Key characteristics of a Living Lab and how the GEO-Academy GEO-Labs cultivate openness, empowerment, realism and spontaneity (adapted from D2.2).

By functioning as Living Labs, GEO-Labs embody the five LL principles of openness, continuity, empowerment, realism, and spontaneity. The GEO-Kit operationalizes these principles in concrete classroom terms:

- **openness**, because the Kit is built on widely available, open hardware and open-source programming environments;
- **continuity**, because the same Kit can support a sequence of activities across multiple lessons, school years and GEO-Concepts;
- **empowerment**, because students themselves assemble, program and interpret the data;

- **realism**, because the Kit captures phenomena that genuinely happen in or around the school; and
- **spontaneity**, because the modularity of the components invites teachers and students to adapt the activities to local interests and contexts.

2.2 Pedagogical Framework and Link to the 5 GEO-Concepts

The GEO-Kit is fully aligned with the GEO-Academy Unified Competence Framework (UCF) and with the pedagogical model developed in WP3 (see [D3.2, Annex I](#)), which combines inquiry-based learning, project-based learning and challenge-based learning under the umbrella of a Whole School Approach. Activities supported by the Kit are designed to embed the “head, heart and hands” philosophy of holistic ESD, ensuring that students engage cognitively, emotionally and practically with the phenomena they are investigating.

Each GEO-Concept addresses a distinct dimension of geospatial literacy and is supported by the Kit in a complementary way. GC1 and GC2 (Cartography, spatial skills and GIS) are addressed through navigation, map literacy and geolocation activities; GC3 (Remote Sensing and Earth Observation) is addressed through sensor-based monitoring of physical phenomena such as ground vibrations, air quality and microclimate variation; GC4 (Map storytelling) is addressed by combining sensor-collected geolocated data with narrative visualizations, including the sonification of data into sound; and GC5 (STEAM, robotics and coding) underpins all activities through the systematic use of programmable boards, sensors and block-based or text-based coding. This deliberate one-to-many mapping means that a single Kit can be redeployed across the full breadth of the curriculum rather than being confined to a single subject.

2.3 Connection to the Three Competency Pillars (Digital, Green, Spatial)

The Kit serves the three competency pillars on which the entire GEO-Academy project is built. On the digital pillar, students develop computational thinking, block-based and text-based programming skills, data acquisition and data-handling literacy, mapped onto DigComp 2.2 competence areas. On the green pillar, the activities address authentic sustainability topics—air quality, urban heat, biodiversity, microclimate, energy, smart lighting—and invite students to interpret data critically and propose evidence-based responses, mapped onto GreenComp² competences such as “embracing complexity” and “acting for sustainability”. On the spatial pillar, geolocation, map reading, spatial reasoning, and the visualization of patterns in space become natural, embedded outcomes of every activity. The Kit is therefore best understood not as a piece of equipment but as a vehicle for integrated competence development.

² Bianchi, G., Pisiotis, U. and Cabrera Giraldez, M., GreenComp The European sustainability competence framework, Punie, Y. and Bacigalupo, M. editor(s), EUR 30955 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-46485-3, doi:10.2760/13286, JRC128040.

2.4 Target Audience

The primary audience of the GEO-Kit and the activities described in this deliverable are in-service and pre-service teachers participating in GEO-Academy training events, and through them, their students across primary, lower-secondary and upper-secondary education. Secondary audiences include teacher trainers, national coordinators of the GEO-Hubs, educational authorities, and members of the broader school community (school leaders, parents and local stakeholders) involved in co-designing GEO-Lab projects. The Kit has been deliberately designed to be usable by teachers without a prior background in electronics or programming, while remaining extensible enough to be valuable for STEAM specialists. Several activities (notably the Map Storytelling Through Sonification activity) are also explicitly designed to support inclusive classroom contexts, including students with visual impairment and neurodiverse learners.

3 GEO-Kit Design and Components

3.1 Design Principles and Selection Criteria

The GEO-Kit was designed and assembled by a subcontractor acting under NUCLIO's supervision, in close consultation with the consortium partners, and was iteratively refined throughout the project based on feedback from training events and pilot classroom implementations. The current configuration of the Kit reflects **four design priorities**: low cost, broad pedagogical applicability across the five GEO-Concepts, low entry barrier for teachers, and robustness to repeated classroom use.

Components for the Kit were selected according to **five criteria**. First, **accessibility**: each component had to be widely available, replaceable and affordable enough to allow several Kits per school. Second, **pedagogical versatility**: each component had to be usable in activities for at least two of the five GEO-Concepts, to maximize reuse and minimize idle equipment. Third, **openness**: priority was given to open hardware and to programming environments with strong educational community support, such as the Microsoft MakeCode block editor for Micro:bit and the Arduino IDE. Fourth, **age-appropriateness**: components had to be safe to handle and programmable using both block-based and text-based languages, so that the same Kit could serve primary and upper-secondary classrooms. Fifth, **alignment with the planned activity catalogue**: every component had to be justified by at least one validated activity scenario.

Three further choices made by the consortium during the design phase deserve to be made explicit. First, the Kit standardises on Micro:bit v2 and Arduino UNO R3 rather than Raspberry Pi, which had been mentioned alongside them in the original proposal. The two retained boards have lower cost, a much shorter ramp-up time for teachers without a programming background, and excellent block-based programming environments (MakeCode and Arduino IDE), while still allowing a progression to text-based code in MicroPython or C/C++ for more advanced classrooms. Raspberry Pi was not excluded in principle but was felt to add cost, complexity (boot times, SD-card management, full Linux administration) and security considerations that were disproportionate to the educational gain at the primary and lower-secondary levels the Kit primarily targets. Second, drones—which the proposal listed among the example experiments—were excluded from the standard Kit. The combination of unit cost, national and EU aviation regulations, in-school safety considerations and insurance constraints made drones impractical to include in a Kit intended for routine, low-friction use by non-specialist teachers; the Earth Observation strand of the project is therefore addressed through the Micro:bit seismometer and the air-quality and agro-climatic activities, and through the use of openly available satellite imagery on the GEOBSERVE platform. Third, the

Kit gives priority to sensors that produce data students can themselves explain—accelerometer, temperature, humidity, light, gas, dust, sound, geolocation—rather than to higher-precision instruments whose readings would arrive as numbers stripped of intuition.

3.2 Common Hardware Components

The full GEO-Kit, in the configuration used for the full set of activities described in Chapter 4, contains a small and deliberately conservative set of components, described in the four subsections below.



Figure 2: GEOKIT main electronic components. From left to right; top row: Arduino UNO R3, BBC Micro:bit (v2), Arduino SD card shield, LCD shield; middle row: temperature and humidity sensor, micro:bit extension board, Arduino GPS module, gas/dust/air quality sensor; bottom row: micro:bit battery packs, Arduino battery pack; breadboard.

3.2.1 Micro:bit and Arduino UNO R3

Two BBC Micro:bit (v2) boards form the heart of the Kit. They host the onboard sensors used in many activities (accelerometer, microphone, light, temperature) and act as the primary programmable platform for younger learners through the block-based MakeCode environment. They communicate with one another via the integrated radio module, which is exploited in several activities (notably the seismometer) to physically separate the sensing unit from the data-logging unit. The Arduino UNO R3 board complements the Micro:bit by providing the platform for activities that require analog inputs, dedicated sensor shields or more elaborate programming—for example, the BME280 environmental sensor and the SD-card shield used in some Cartography/GIS activities.

3.2.2 Sensors (Temperature/Humidity, Air Quality, Sound, Dust)

The sensor set covers the principal environmental variables addressed by the Kit's activities. A DHT22 temperature and humidity sensor, complemented by a BME280 (which adds barometric pressure), supports microclimate monitoring and agro-climatic activities. A dust sensor and an MQ-135 air quality sensor for gases enable urban air-quality monitoring projects. Sound level is captured by the Micro:bit v2 onboard microphone, which avoids adding an external module for this variable. All sensors were chosen to be plug-and-play through Grove or jumper cables, minimizing soldering and accelerating classroom deployment.

3.2.3 Geolocation Module (NEO-6M)

A NEO-6M GPS receiver provides geolocation data for outdoor activities and for any project in which sensor readings need to be associated with a real-world location. The module is connected to either the Micro:bit (via a Keystudio KS0297 expansion board) or the Arduino UNO; in practice, due to the absence of dedicated block-based libraries for the Micro:bit, the NEO-6M is more commonly used with Arduino in the current activity set, which gives teachers a natural progression from MakeCode to written code. The Peddy Paper activity (Section 4.4) is the canonical use case for this module.

3.2.4 Actuators and Accessories

The Kit includes a small DC motor and a bottle cork, which together provide the controllable source of vibration used in the seismometer activity. Battery packs (for the Micro:bit and for the DC motor), AA batteries, jumper cables, a USB micro-B to USB type-A cable, an SD-card shield for the Arduino, and —for the Smart Lighting activity— an optional external LED with a 220 Ω resistor and a PIR motion sensor complete the bill of materials. Two distinct power supplies —one for the sensing Micro:bit and one for the motor— are deliberately included in the seismometer activity so that vibrations from the motor do not contaminate the sensor reading through the power line.

3.3 Software, Programming Environments and Libraries

The Kit is supported by a small, deliberately conservative set of software tools. The Micro:bit is programmed primarily through the Microsoft MakeCode block-based editor, which runs in any browser without installation and offers a straightforward migration path to MicroPython for older students. The Arduino UNO is programmed through the Arduino IDE, using the standard set of libraries for the included sensors. Data are exported as CSV from the Micro:bit serial console or from the Arduino, and can then be imported into spreadsheet software, and into the GIS and visualization tools curated on the GEOBSERVE platform (QGIS, Google Earth, ArcGIS Online and ArcGIS StoryMaps), or into sonification tools such as TwoTone and Sonic Pi. Sample programs, wiring diagrams, and step-by-step worksheets are made available to teachers through GEOBSERVE.

3.4 Kit Configurations per GEO-Concept

The same physical components are reorganized into four functional sub-kits, one per GEO-Concept cluster. This modular framing helps teachers select only the items they need for a specific lesson rather than handling the whole bill of materials at once.

3.4.1 GC1 & GC2 — Cartography, Spatial Skills and GIS

For GC1 and GC2, the Kit configuration centres on one Micro:bit v2 (using its onboard sensors for sound, light and temperature), a DHT22 temperature and humidity sensor, a NEO-6M geolocation module connected via a Keystudio KS0297 expansion board, an Arduino UNO R3, a BME280 sensor and an SD-card shield for Arduino. This configuration supports activities that combine outdoor data collection with map literacy and basic GIS work, including the Peddy Paper Adventure described in Section 4.4.



Figure 3: Components of the GC1&2 (Cartography, Spatial Skills and GIS) configuration of the GEO-Kit, including the Arduino UNO R3 and micro:bit controllers, temperature and humidity sensors, and GPS module.

3.4.2 GC3 — Remote Sensing, Earth Observation and Satellite Applications

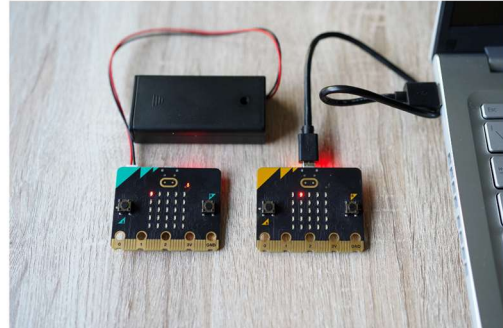
For GC3, two configurations are used. The first, dedicated to the seismometer activity (Section 4.2), reduces the Kit to two Micro:bit boards (sender and receiver), two AA batteries to power the sender Micro:bit, two AA batteries to power the DC motor, the DC motor itself and a bottle cork mounted on the motor shaft to produce controllable vibrations. The second, dedicated to air-quality (Section 4.3) and agro-climatic monitoring (Section 4.6), couples the Micro:bit v2 with the MQ-135 gas sensor, the DHT22 temperature/humidity module, a breadboard, jumper cables and a battery pack.

GC3: Remote sensing (RS), Earth observation (EO) and satellite applications

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KIT components:

- Two Micro:bit
 - Micro:bit 1 ("sender", green in image): powered by batteries
 - collects data and send it via radio to Micro:bit 2 ("receiver");
 - Micro:bit 2 ("receiver", orange in image): connected to a computer
 - receives data from Micro:bit 1.
- 2 AA batteries to power the Micro:bit "sender";
- 2 AA batteries to power the DC motor;
- Bottle cork connected to DC motor
 - produce vibrations near the Micro:bit "sender";
 - shift cork position for different vibrations.



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Figure 4: Components of the GC3 (Remote Sensing, Earth Observation and Satellite Applications) configuration of the GEO-Kit, including two micro:bit controllers and battery pack.

3.4.3 GC4 — Visualization and Map Storytelling

GC4 activities are primarily software-based and rely on the GIS and visualization tools curated on the GEOBSERVE platform, in particular ArcGIS StoryMaps, Google Earth Web, QGIS and dedicated sonification environments (TwoTone, Sonic Pi, p5.js Sound Library). When the underlying data are collected by the students themselves with the GEO-Kit —for example air-quality or agro-climatic data destined for sonification— the same hardware as in Sections 4.3 and 4.6 is mobilized, thereby closing the loop between data acquisition and data storytelling.

3.4.4 GC5 — STEAM Education, Robotics and Coding

For GC5, the Kit is assembled in its richest configuration, including an Arduino UNO R3, two Micro:bit boards with AA batteries, the temperature and humidity sensor, the air quality sensor for gases, the dust sensor, the Micro:bit onboard microphone for sound level, the geolocation module, the DC motor with its battery pack, and the necessary cables. Specific GC5 activities mobilize additional components: the smart-lighting activity (Section 4.7) adds an optional external LED with a 220" resistor and, for the advanced extension, a PIR motion sensor. This configuration is the one delivered to school GEO-Labs and is the one used most extensively in the consortium's STEAM training workshops.

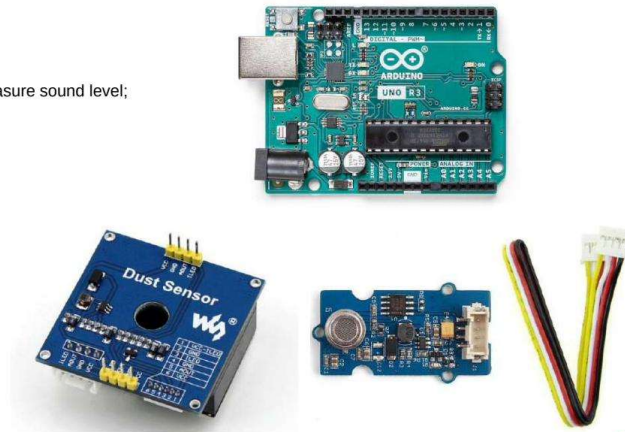


GC5: STEAM education, robotics and coding

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KIT components:

- One Arduino UNO R3;
- Micro:bit onboard microphone to measure sound level;
- Air quality sensor for gases;
- Air quality sensor for dust;
- Geolocation module (NEO-6M).



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Figure 5: Components of the GC5 (STEAM, Robotics and Coding) configuration of the GEO-Kit, including the Arduino UNO R3, the dust sensor, the air-quality sensor for gases and the geolocation module (NEO-6M).

4 GEO-Kit Activities and Experiments

4.1 Overview of the Activities Catalogue

The GEO-Kit activities translate the conceptual architecture of GEO-Academy —five GEO-Concepts crossed with three competency pillars (digital, green, spatial)— into a coherent set of inquiry-based experiences that teachers can implement in their own classrooms. Rather than offering isolated experiments, the catalogue is designed as a **modular and progressive ecosystem** in which each activity reuses the same core hardware (the micro:bit v2 and, where relevant, the Arduino UNO R3, sensors and the NEO-6M GPS module) while exploring a distinct facet of geospatial reasoning, environmental observation or computational thinking.

The catalogue presented in this section comprises six activities developed and piloted within the project:

#	Activity	Primary GEO-Concept	Dominant pillars
4.2	Building a Seismometer with Micro:bit	GC5 — STEAM, Robotics & Coding	Digital + Spatial
4.3	Investigating Air Quality	GC3 — Remote Sensing & Earth Observation	Green + Digital
4.4	Spatial Skills and Map Literacy (Peddy Paper)	GC1 & GC2 — Cartography, Spatial Skills, GIS	Spatial + Digital
4.5	Map Storytelling Through Sonification	GC4 — Visualization & Map Storytelling	Digital + Spatial
4.6	Agro-Climatic Monitoring with micro:bit	GC3 — Remote Sensing & Earth Observation	Green + Spatial
4.7	Smart Lighting and Energy Efficiency	GC5 — STEAM, Robotics & Coding	Green + Digital

All activities share four design invariants:

- **Inquiry-based 4-step pedagogical cycle** — *Introduction & engagement* → *Questioning and hypothesis* → *Experimentation, revision and conclusions* → *Sharing and reflection*. This cycle ensures methodological consistency across kits and aligns the catalogue with the GEO-Academy training model developed in WP3.

- **Low-cost, replicable hardware** — every activity can be implemented with one or two components from the standard GEO-Kit, so that schools without specialized laboratories can still participate.
- **Curricular bridging** — each activity is mapped to upper-primary and lower-secondary curriculum domains (science, geography, mathematics, ICT, civic education, arts), enabling teachers to integrate it within existing subject planning rather than as an extracurricular add-on.
- **Outputs that feed the GEOBSERVE Community of Practice** — student data, sound files, maps and reflections are designed to be shareable on the GEOBSERVE platform (see Section 6), turning each classroom implementation into a contribution to the European GEO-Academy network.

For each activity, a complete **GEO-Kit Activity Guide** and, where applicable, a **Technical Reference** document are made available as annexes and, in open-access form, on the GEOBSERVE portal. The summaries below condense the scientific rationale, the classroom procedure, and the link to the GEO-Academy framework.

4.2 Activity: Building a Seismometer: Exploring Vibrations with Micro:bit

This activity invites students to take on the role of young seismologists, using the micro:bit v2 as a low-cost seismometer to detect, record and interpret ground vibrations. The pedagogical entry point is a deliberately tangible question — *“If the ground beneath us shifts, how can we know it happened?”* — which opens the door to a discussion of seismic waves, sensor technology and the role of monitoring networks in disaster preparedness.

In the experimental phase, students assemble a paired-micro:bit setup: one device acts as a **sender**, reading three-axis acceleration data through its built-in accelerometer; the other acts as a **receiver**, collecting the data via radio for visualization in the MakeCode Data Viewer. A simple DC motor with an off-centre cork generates controlled vibrations, allowing learners to manipulate variables such as distance, surface type, and rotation speed. They compare their classroom signals with real seismograms from the EMSC and the US Geological Survey, learning to distinguish noise from signal and to reason about magnitude, frequency and propagation.

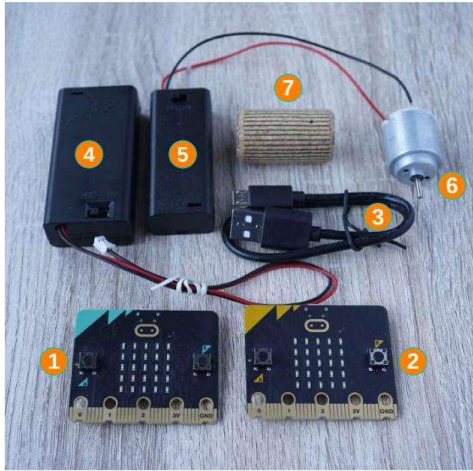
GEO-Kit components used: 2 × micro:bit v2 with battery packs, DC motor, 2×AA battery holder with on/off button, bottle cork, jumper cables.

Pedagogical anchoring: the activity directly serves **GC5 — STEAM Education, Robotics and Coding** while reinforcing data literacy and computational thinking from the **Digital pillar**, and a clear **Spatial pillar** dimension by connecting local measurements to global seismic activity.

Outcomes from the classroom can be uploaded as a *Seismic Data Gallery* on GEOBSERVE, fostering peer comparison across the European GEO-Academy network.

Field	Description
Primary GEO-Concept	GC5 — STEAM Education, Robotics & Coding
Dominant pillars	Digital + Spatial
Target audience	Upper-primary and lower-secondary teachers; classroom use age 12–16
Estimated duration	4–6 lessons of 45–60 min (engagement → assembly → measurements → analysis → sharing)
GEO-Kit components	2 × micro:bit v2 (sender/receiver), DC motor, 2×AA battery holder with on/off button, bottle cork, jumper cables, USB cables
Software / platforms	MakeCode (block-based), MakeCode Data Viewer; optional spreadsheet (CSV export); EMSC and U.S. Geological Survey portals for comparison
Key learning outcomes	Understand seismic wave generation and detection; program an accelerometer-based sensor; collect, transmit and visualise time-series data; distinguish noise from signal; interpret magnitude and frequency
Curriculum links	Physics (mechanics, waves); ICT (block programming, radio communication); Mathematics (graphs, time series); Earth sciences
EU competence frameworks	DigComp 2.2 — areas 1, 3, 5; Key Competences 2018 — STEM, digital
GEOBSERVE deliverables	Class Seismic Data Gallery (datasets + visualisations); short reflection post

Geo-KIT hardware used in this experiment



- 1) Micro:bit "Sender": detects vibrations and send them via radio to micro:bit "Receiver" (item #2). Powered by battery pack (item #4);
- 2) Micro:bit "Receiver": receives data via radio from micro:bit "Sender", records it in its internal memory, and send it to PC (via USB, item #3) to automatically monitor data;
- 3) USB micro-B to USB type A cable, to connect one micro:bit to a PC;
- 4) Battery pack to power one micro:bit;
- 5) Battery pack to power DC motor;
- 6) DC motor to induce vibrations;
- 7) Bottle cork, used with DC motor to create different magnitudes of vibrations.

Figure 6: Labelled hardware of the GEO-Kit seismometer setup, as used in the GEO-Academy Winter School 2025 in Vienna: (1) sender Micro:bit, (2) receiver Micro:bit, (3) USB cable, (4) Micro:bit battery pack, (5) motor battery pack, (6) DC motor, (7) bottle cork.

4.3 Activity: Investigating Air Quality: Understanding Environmental Change Through Classroom Science

Air quality is one of the most direct entry points into Education for Sustainable Development: it is invisible, daily, and immediately relevant to students' health and surroundings. This activity guides learners through a complete inquiry cycle, from situating the problem within the broader debate on greenhouse gases and climate change to designing and running their own measurement campaign in and around the school.

In the engagement phase, teachers introduce the greenhouse effect through hands-on or virtual laboratories and challenge students to compile evidence from credible sources such as *Our World in Data*. Students then map possible local pollution sources —traffic corridors, fuel stations, construction sites, kitchen exhausts— using Google Maps or an equivalent tool, and formulate testable hypotheses (for example, that classroom CO₂ rises significantly when windows are kept closed, or that air quality degrades during rush hour). In the experimental phase, they build a portable **air quality station** based on a micro:bit, the MQ-135 gas sensor, and the DHT22 temperature/humidity module and run a measurement protocol over several days and varying weather conditions. Results are cross-referenced with traffic data and discussed in light of the original hypotheses.

GEO-Kit components used: micro:bit v2, MQ-135 gas sensor, DHT22 temperature/humidity module, breadboard, jumper cables, battery pack.

Pedagogical anchoring: the activity is anchored in **GC3 — Remote Sensing, Earth Observation and Satellite Applications** (situating local readings within a broader EO context), and operationalises the **Green** and **Digital** pillars, while explicitly addressing GreenComp competences related to *embracing complexity* and *acting for sustainability*. Class data and recommendations can be geo-mapped on a class website and contributed to GEOBSERVE.

Field	Description
Primary GEO-Concept	GC3 — Remote Sensing, Earth Observation & Satellite Applications
Dominant pillars	Green + Digital
Target audience	Primary and secondary teachers; classroom use age 10–18
Estimated duration	6–8 lessons of 45–60 min spread over 1–2 weeks (multi-day measurement campaign)
GEO-Kit components	micro:bit v2, MQ-135 gas sensor, DHT22 temperature/humidity module, breadboard, jumper cables, battery pack
Software / platforms	MakeCode; spreadsheet for analysis; Google Maps or OpenStreetMap for mapping pollution sources; Our World in Data for global trends
Key learning outcomes	Understand the greenhouse effect and its link to air quality; design a measurement protocol with controlled variables; correlate environmental data with contextual factors (traffic, weather); draft evidence-based recommendations
Curriculum links	Environmental science / chemistry; geography (urban environment); ICT; civic education and ESD
EU competence frameworks	DigComp 2.2 — areas 1, 3, 5; GreenComp — Embracing complexity, Acting for sustainability; Key Competences 2018 — STEM, citizenship
GEOBSERVE deliverables	Geo-mapped air-quality dataset; class report with policy recommendations

4.4 Activity: Exploring Spatial Skills and Map Literacy: A Cartography & GIS Peddy Paper Adventure

This activity reframes the traditional outdoor *Peddy Paper* as a structured inquiry into spatial literacy and basic GIS. Its rationale is that map reading is a fundamental —and often overlooked— scientific skill that bridges geography, mathematics, art and digital technology, and that students best develop it by alternating between physical exploration and digital representation of the same space.

After an introductory discussion comparing topographic, thematic and digital maps (Google Earth, OpenStreetMap, ArcGIS Online), students formulate hypotheses about navigation strategies and the relative effectiveness of mental versus measured maps. Teachers then prepare a base map of the schoolyard or neighbourhood with checkpoints described through cartographic clues. In small groups, students follow the route using compasses, GPS-enabled phones (Geo Tracker, Google Maps, ArcGIS Field Maps) and the NEO-6M module of the GEO-Kit when more rigorous georeferencing is required. At each waypoint they collect coordinates, photographs and field notes; back in class, they overlay their data on a digital map, compare it with their initial sketches and produce a final *Map Fair* or interactive Story Map.

GEO-Kit components used: micro:bit v2 with NEO-6M GPS module, Keystudio KS0297 expansion board, jumper cables; complemented by mobile devices and an open-source mapping platform (QGIS or ArcGIS Online).

Pedagogical anchoring: the activity sits at the heart of **GC1 & GC2 — Cartography, Spatial Skills and GIS** and gives the **Spatial pillar** its most direct expression in the catalogue. It also reinforces the **Digital pillar** through the use of GIS tools and digital storytelling, and feeds naturally into Section 4.5 (sonification) by producing georeferenced datasets that can be re-used in subsequent activities.

Field	Description
Primary GEO-Concept	GC1 & GC2 — Cartography, Spatial Skills and GIS
Dominant pillars	Spatial + Digital
Target audience	Primary and secondary teachers; classroom use age 10–18 (route complexity adapted by level)
Estimated duration	4–5 lessons of 45–60 min, with at least one outdoor session of 90–120 min
GEO-Kit components	micro:bit v2, NEO-6M GPS module, Keystudio KS0297 expansion board, jumper cables, battery pack; complemented by participants' smartphones
Software / platforms	MakeCode (GPS data logging); Google My Maps / ArcGIS Online / QGIS for base maps; Geo Tracker / ArcGIS Field Maps for waypoints; ArcGIS StoryMaps / Google Earth Web for the final story map
Key learning outcomes	Read and interpret cartographic symbols, scales and coordinates; collect georeferenced field data; compare mental and measured maps;

Field	Description
	produce a digital story map combining narrative, photos and geographic layers
Curriculum links	Geography and earth sciences; mathematics (scale, coordinates, distance); ICT (GIS); arts (visual narrative); physical education (orientation)
EU competence frameworks	DigComp 2.2 — areas 1, 2, 3; Key Competences 2018 — STEM, digital, learning to learn
GEOBSERVE deliverables	Story map / interactive map; field-data datasets; teacher reflection on outdoor implementation

4.5 Activity: Map Storytelling Through Sonification: Turning Geospatial Data into Sound

This activity introduces students to *sonification*—the systematic translation of data into sound—as a complementary mode of representing geospatial information. Its starting question, “*If a map could sing, what story would it tell?*”, opens an interdisciplinary conversation that connects geography, computer science, music and civic awareness, and offers a powerful inclusion lever for students with visual impairment or with non-dominant learning profiles.

After exploring reference projects such as NASA Data Sonification, ESA’s ‘*Sound of the Earth*’ and the ‘Data Sonification Archive’, students choose a meaningful georeferenced dataset (population density, CO₂ emissions, renewable energy adoption, biodiversity loss...) from open sources such as Eurostat, the European Data Portal or the Copernicus Climate Data Store. Each group formulates hypotheses about how data should map onto sound (pitch, rhythm, volume, instrument) and tests them using free tools—**TwoTone** for CSV-to-sound conversion, **Sonic Pi** for live coding, or **p5.js Sound Library** combined with Google Earth Engine for advanced layering. The cycle closes with a *Sound of Data* exhibition, in which each soundscape is presented alongside its underlying map.

GEO-Kit components used: the activity is primarily software-based; the GEO-Kit hardware is mobilized when students choose to sonify data they have themselves collected with the micro:bit (e.g. air quality, agro-climatic readings), thus closing the loop between Sections 4.3, 4.6 and 4.5.

Pedagogical anchoring: the activity is the centerpiece of **GC4 — Visualization and Map Storytelling**. It develops the **Digital pillar** (data literacy, computational thinking) and the

Spatial pillar (geospatial reasoning), while opening a strong **arts and inclusion** dimension that is often under-represented in STEAM curricula. Sound files and accompanying maps are prime candidates for publication on GEOBSERVE.

Field	Description
Primary GEO-Concept	GC4 — Visualisation and Map Storytelling
Dominant pillars	Digital + Spatial (with explicit Arts and Inclusion dimension)
Target audience	Secondary teachers; classroom use age 13–18; particularly suitable for inclusive classrooms (visual impairment, neurodiverse learners)
Estimated duration	4–6 lessons of 45–60 min
GEO-Kit components	Software-centric activity; GEO-Kit hardware mobilised when sonifying datasets collected with the micro:bit (loop with 4.3 / 4.6)
Software / platforms	TwoTone (CSV → sound); Sonic Pi (live coding); p5.js Sound Library + Google Earth Engine for advanced layering; SoundCloud / Padlet / Google Sites for the exhibition; data sources: Eurostat, European Data Portal, Copernicus Climate Data Store
Key learning outcomes	Translate quantitative data into auditory representation; map data attributes onto sound parameters (pitch, rhythm, volume); compare visual and auditory representations of the same dataset; produce a sound-and-map composition with an explicit narrative
Curriculum links	Geography; ICT and computational thinking; mathematics (statistics, mappings); music; arts; civic education
EU competence frameworks	DigComp 2.2 — areas 1, 2, 3; Key Competences 2018 — digital, cultural awareness and expression
GEOBSERVE deliverables	Sonified soundscape (audio file); accompanying map and short reflection; eligible for the GeoVoices competition

4.6 Activity: Agro-Climatic Monitoring with micro:bit

This activity uses the micro:bit v2 as a portable agro-climatic sensing device, allowing students to investigate how land cover, vegetation, shading, and surface materials affect local microclimates. The rationale is to make the abstract notion of *climate* tangible at the scale of the school: by comparing readings taken at ground level in contrasting locations—for example a paved courtyard versus a vegetated area or a school garden—learners experience first-hand the role of vegetation in temperature regulation and the relevance of microclimatic variation for sustainable agriculture and ecosystem health.

Following a clearly defined measurement protocol (fixed sensor height of approximately 10 cm above ground, 1–2 minute stabilization time, identical procedure across locations), students program the micro:bit in MakeCode to read **temperature** and **light level** on demand: button A displays temperature, button B displays light level, with the LED matrix cleared between readings to avoid information overload. Values are logged manually in a structured field notebook together with contextual observations (shading, wind, soil type, nearby vegetation). In the analysis phase, learners focus on **relative differences** between sites rather than absolute values, mirroring real agro-climatic field practice. As an optional extension, the DHT22 sensor can be added for higher-precision temperature and humidity readings, and measurements can be repeated across times of day.

GEO-Kit components used: micro:bit v2 with battery pack; optionally DHT22 temperature/humidity module, breadboard and jumper cables for the extension.

Pedagogical anchoring: the activity contributes to **GC3 — Remote Sensing, Earth Observation and Satellite Applications** by producing the kind of in-situ data that supports validation of EO products. It develops the **Green** and **Spatial** pillars and connects to ESD and to GreenComp competences on systems thinking and sustainable practice. Datasets are well suited for cross-school comparison via GEOBSERVE.

Field	Description
Primary GEO-Concept	GC3 — Remote Sensing, Earth Observation & Satellite Applications
Dominant pillars	Green + Spatial
Target audience	Primary and secondary teachers; classroom use age 10–16; ideal for school gardens contexts
Estimated duration	3–4 lessons of 45–60 min, ideally repeated across seasons
GEO-Kit components	micro:bit v2 with battery pack; optionally DHT22 temperature/humidity module, breadboard, jumper cables for the higher-precision extension
Software / platforms	MakeCode (button A → temperature, button B → light level); spreadsheet for tabulation and basic plotting; optional comparison with Copernicus Climate Data
Key learning outcomes	Apply a rigorous comparative measurement protocol (fixed height, stabilisation, identical procedure); reason about microclimate drivers (vegetation, shading, surface materials); interpret relative differences

Field	Description
	rather than absolute values; relate local observations to sustainable agriculture and ecosystem health
Curriculum links	Biology and ecology; geography; environmental sciences; ICT; ESD
EU competence frameworks	GreenComp — Systems thinking, Embodying sustainability values; DigComp 2.2 — areas 1, 5; Key Competences 2018 — STEM, citizenship
GEOBSERVE deliverables	Comparative microclimate dataset; map of measurement points; teacher protocol notes

4.7 Activity: Smart Lighting and Energy Efficiency

This activity invites students to design a simplified **smart streetlight simulation** that adapts its output to ambient conditions, using the micro:bit v2 and its built-in light-sensing capability. Public lighting is a deliberately chosen entry point: it is a tangible, daily example of the trade-offs between safety, comfort, energy consumption and light pollution that lie at the heart of sustainable urban design.

After exploring real-world examples of smart lighting initiatives—including European Commission resources on energy-efficient public lighting and International Dark-Sky Association materials on light pollution—students formulate hypotheses about when artificial lighting is genuinely needed and how a sensor-based system could reduce energy use without compromising safety. In the experimental phase, they program the micro:bit in MakeCode to read ambient light levels (range 0–255) and apply simple control logic: a basic on/off rule based on a threshold, then a dimming behaviour using analogue values (`analog write pin`) and conditional `if / else if / else` blocks to map light ranges to LED intensity. The system is tested under controlled scenarios (direct light, shade, covered sensor) and observations are documented systematically. Optional extensions include connecting an external LED for clearer visualisation, integrating a PIR motion sensor for presence-based lighting, and logging values for further analysis.

GEO-Kit components used: micro:bit v2 with battery pack; optionally LED RGB 5 mm with 220 Ω resistor, breadboard and jumper cables; PIR motion sensor for the advanced extension.

Pedagogical anchoring: the activity addresses **GC5 — STEAM Education, Robotics and Coding** while serving the **Green** and **Digital** pillars. It opens a clear bridge to civic and policy discussions on smart cities, SDG 7 (affordable and clean energy) and SDG 11 (sustainable cities and communities), making it particularly suitable for cross-curricular work between science, ICT and citizenship education.

Field	Description
Primary GEO-Concept	GC5 — STEAM Education, Robotics & Coding
Dominant pillars	Green + Digital
Target audience	Primary and secondary teachers; classroom use age 10–18
Estimated duration	3–4 lessons of 45–60 min (basic on/off → dimming → optional extensions)
GEO-Kit components	micro:bit v2 with battery pack; optionally LED RGB 5 mm with 220 Ω resistor, breadboard, jumper cables; PIR motion sensor for the advanced extension
Software / platforms	MakeCode (light-level reading, conditional logic, analog write / PWM); references on European Commission energy-efficient lighting and International Dark-Sky Association resources
Key learning outcomes	Read and threshold a light sensor; design conditional control logic (if / else if / else); approximate dimming via analogue output; reason about energy consumption, safety and light pollution trade-offs
Curriculum links	Physics (light, energy); ICT (control logic, PWM); civic education (smart cities, SDGs); design and technology
EU competence frameworks	DigComp 2.2 — areas 3, 5; GreenComp — Acting for sustainability; Key Competences 2018 — STEM, citizenship
GEOOBSERVE deliverables	Code repository of the smart-lighting prototype; classroom poster on energy savings; short policy statement linking to SDG 7 and 11

4.8 Curriculum Integration and Learning Outcomes

The six activities described above were not designed as isolated experiments but as **curriculum-integrable inquiry units** that teachers can plug into existing subject planning. This sub-section makes that integration explicit along three complementary axes: (i) intended learning outcomes, (ii) curriculum domains and subject bridges, and (iii) alignment with European competence frameworks.

Intended learning outcomes

Across the catalogue, the GEO-Kit activities have been designed to develop a shared core of transversal learning outcomes. By the end of an activity cycle, learners are expected to:

- **Frame a researchable question** about an environmental, spatial or technological phenomenon and translate it into one or more testable hypotheses.

- **Plan and execute a measurement protocol** using GEO-Kit hardware, applying basic principles of data quality (calibration, repetition, controlled variables, contextual annotation).
- **Read, manipulate and represent geospatial or sensor data** in at least one digital environment (MakeCode, a spreadsheet, a GIS tool, a sonification platform, GEOBSERVE).
- **Interpret results in light of their initial hypotheses**, distinguishing supported claims from open questions and identifying sources of uncertainty.
- **Communicate findings in a structured form**—a poster, a story map, a soundscape, a webinar, a GEOBSERVE post—adapted to a non-specialist audience.
- **Connect local observations to broader European and global contexts**, including the relevant Sustainable Development Goals.

Each activity refines this core into discipline-specific outcomes (e.g. understanding of seismic wave propagation in 4.2; awareness of greenhouse gas dynamics in 4.3; spatial reasoning and GIS literacy in 4.4 and 4.6; multimodal data representation in 4.5; energy systems and control logic in 4.7).

Curriculum domains and subject bridges

The catalogue is deliberately positioned at the intersection of several school subjects, which supports both standalone use and cross-disciplinary projects:

- **Science (physics, biology, environmental sciences):** 4.2 (mechanics, waves), 4.3 (atmospheric chemistry, ecology), 4.6 (microclimate, ecosystems).
- **Geography and earth sciences:** 4.3, 4.4, 4.5, 4.6—all activities make spatial reasoning and georeferenced data central.
- **Mathematics:** quantitative analysis, units, scales, basic statistics across the catalogue; symbolic and graphical representation in 4.4 and 4.5.
- **ICT and computational thinking:** all six activities use block-based programming (MakeCode), with 4.5 and 4.7 introducing more elaborate logical structures.
- **Arts and music:** 4.5 (sonification), with extension opportunities in 4.4 (story maps).
- **Civic education and ESD:** 4.3, 4.6 and 4.7 open explicit policy and citizenship discussions on air quality, sustainable agriculture and energy use.

This intentional cross-subject footprint makes the GEO-Kits a strong vehicle for integrated STEAM projects, school-wide weeks on sustainability or Erasmus+ KA1 student mobilities themed on environmental observation.

Alignment with European competence frameworks

The activities are mapped onto three reference frameworks that structure the GEO-Academy approach:

- **DigComp 2.2**³ — particularly competence areas 1 (*Information and data literacy*), 3 (*Digital content creation*) and 5 (*Problem solving*), with activities 4.5 and 4.7 also addressing competence 2 (*Communication and collaboration*).
- **GreenComp** — across the four competence areas, with strongest emphasis on *Embodying sustainability values*, *Embracing complexity in sustainability* and *Acting for sustainability*; activities 4.3, 4.6 and 4.7 are especially aligned.
- **Key Competences for Lifelong Learning**⁴ (**Council Recommendation 2018**) — notably the *Mathematical, scientific and digital* competence, the *Personal, social and learning to learn* competence, and *Citizenship*.

Together, these alignments ensure that every implementation of a GEO-Kit activity contributes not only to local subject learning, but also to the broader European competence agenda that GEO-Academy is committed to advancing, and that teacher-facing outputs (lesson plans, evaluation rubrics, student artefacts) can be unambiguously positioned within the qualifications and CPD frameworks of partner countries.

³ Vuorikari, R., Kluzer, S. and Punie, Y., DigComp 2.2: The Digital Competence Framework for Citizens - With new examples of knowledge, skills and attitudes, EUR 31006 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-48882-8, doi:10.2760/115376, JRC128415.

⁴ European Commission: Directorate-General for Education, Youth, Sport and Culture, Key competences for lifelong learning, Publications Office, 2019, <https://data.europa.eu/doi/10.2766/569540>

5 Implementation in Training Events and Schools

5.1 Integration with National GEO-Academy Hubs and School GEO-Hubs

Seven National GEO-Academy Hubs were established under D4.1, one in each consortium country: Austria, Bulgaria, Cyprus, France, Greece, Portugal and Sweden. Each Hub is a physical and organisational point of contact that connects the consortium partners to a network of schools and to the broader teacher community in that country. School Community GEO-Hubs, located in individual schools or clusters of schools, act as the front line of implementation. The GEO-Kit is delivered to and shared through these hubs, ensuring that the Kit becomes a community resource rather than the property of a single classroom, and is supported by national coordinators who provide pedagogical mentoring and basic technical support.

The Hubs are also the link between the physical Kit and the digital GEOBSERVE platform: each national hub group on GEOBSERVE hosts the relevant Kit documentation, code samples, lesson plans and reports, so that teachers can prepare an activity online before borrowing the Kit, and document their classroom outcomes back on the platform afterwards. This is the same logic implemented in seven national hub groups (GEO-Hub Austria, Bulgaria, Cyprus, France, Greece, Portugal and Sweden) and the International GEO-Hub group described in D4.2.

5.2 Use in Training Events (Local, National, International)

At national and local level, partners have collectively delivered a dense programme of training events, ranging from short three-hour workshops to multi-month blended courses. As reported in D5.2, during the first implementation year (M12–M24) the consortium organised 28 training events plus two week-long international development courses (the Summer School in Marathon, Greece and the Winter School in Vienna, Austria), reaching 677 educators in total—273 pre-service teachers, 357 in-service teachers and 47 teachers trained virtually. The GEO-Kit was used in a sub-set of these events, primarily those that addressed GC3 (Remote Sensing/Earth Observation) and GC5 (STEAM, robotics and coding); in many other events, the Kit was presented as an option for follow-up classroom activities. The three subsections that follow detail the use of the Kit in the two international training events that have shaped its current form, and in the national training activities organised through the Hubs.

5.2.1 Winter School Vienna

The five-day International Development Course “GEO-Academy Winter School 2025”, hosted by the Austrian Space Forum (ÖWF) at KKH Vienna from 10 to 14 February 2025, gave the GEO-Kit one of its most visible showcases. The programme combined keynotes on Earth Observation (including the “Blue Marble – The Earth Seen from Space” talk), workshops on the UCF, sessions on map storytelling for social and natural sciences, sea ice monitoring from space, analog mission mapping inspired by space exploration, and a dedicated “GEO-Kit”

workshop in which participants assembled and programmed the Micro:bit-based seismometer.



Figure 7: GEO-kit being used in the international training workshops in Portugal (left) and Austria (right).

The closing days of the Winter School included a workshop on fire propagation modelling using Micro:bit—where participants learned to simulate how wind and elevation affect fire spread, blending environmental science, coding and spatial reasoning—and a session on early warning systems for earthquakes, again using the Micro:bit-powered GEO-Kit. Participating teachers left Vienna having physically built and used the Kit themselves, which substantially lowered the activation barrier for adopting it in their classrooms upon return.

5.2.2 Summer School Sesimbra

The third International Development Course, the “GEO-Academy Summer School 2025”, was hosted by NUCLIO in Sesimbra, Portugal, in July 2025. Building on the experience of the first Summer School in Marathon (Greece, 7–12 July 2024, organised by Ellinogermaniki Agogi and bringing together 30 teachers across the consortium countries for 25 hours of workshop-based training), the Sesimbra edition placed the refined GEO-Kit at the centre of the programme. Participants worked directly with the activities described in Chapter 4—seismometer, air quality, Peddy Paper, sonification, agro-climatic monitoring and smart lighting—with each activity introduced through its Activity Guide and accompanied by its Technical Reference document published on GEOOBSERVE.

The Sesimbra Summer School also served as the principal site for validating the curriculum-integration framing of Section 4.8: teachers were invited to map each activity onto their own national curricula and to identify the cross-subject bridges that worked best in their teaching context.

5.2.3 National Training Activities

In parallel with the international events, the seven National Hubs delivered a rich programme of local and national training activities featuring the GEO-Kit. In Austria, the University College of Teacher Education Tyrol (PHT) organised ten hub-led events, several of which used the GEO-Kit—including a lesson on earthquake detection successfully implemented at Realgymnasium Schwaz. In Portugal, NUCLIO ran the blended “Sustainability and Citizenship” programme (25 hours face-to-face plus 25 hours independent work) across the 2024–25 and 2025–26 academic years, with the Kit anchoring the STEAM and Earth Observation strands. In Cyprus, the Cyprus Pedagogical Institute (CPI) and the European University of Cyprus (EUC) hosted four and several events respectively, integrating Micro:bit-based sensing with GIS, map storytelling and inclusive ESD pedagogies. In Greece, EA, NTUA and SPOTIN ran joint workshops covering all five GEO-Concepts, with the Kit’s STEAM configuration featured in “Mapping my school yard with Arduino”, “Building a Seismograph”, “Cartography & GIS Peddy Paper” and related school activities. In Bulgaria, the Professional Forum for Education (PFE) delivered the Kit in three-hour STEAM workshops within the National Teacher Academy, while in France and Sweden, Eurisy and Lund University respectively used the Kit in dissemination and outreach events that prepared the ground for the third year of school implementation.

5.3 Pilot Implementation in Schools — Selected Case Studies

Direct classroom implementation of the Kit by trained teachers has been documented by partners through the national Training Implementation Reports. The following case studies illustrate the diversity of contexts in which the Kit has been used.

In Portugal, the six regional GEO-Academy Hubs coordinated by teacher-ambassadors who had attended the international Summer and Winter Schools served as local anchor points

where teachers received continuous training, mentoring and peer support throughout the school year. A central element of the implementation was the use of the GEO-Kit to build and program Micro:bit-based seismometers, delivered, for example, at St. Julian's and at Escola Secundária Maria Lamas. These were complemented by initiatives such as urban green-space mapping with Open Street Map at Agrupamento de Escolas de Abação and at AE Sophia de Mello Breyner, environmental monitoring campaigns and map-based storytelling exercises across primary, middle and high school levels.

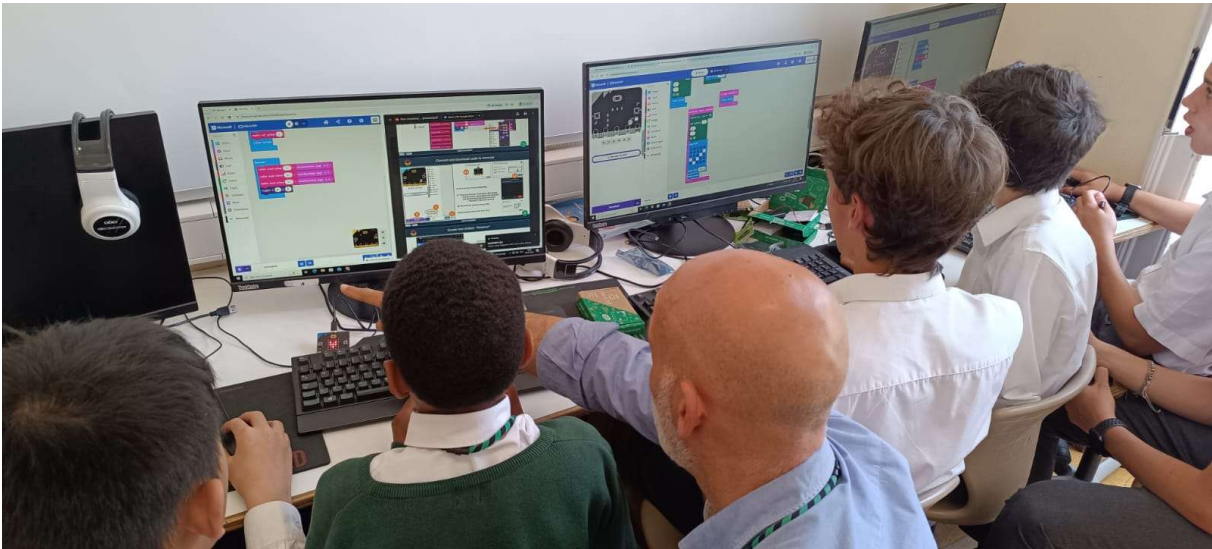


Figure 8: GEO-kit classroom implementation (Seismometer activity) with 8th grade students from St- Juliens school in Carcavelos, Portugal.

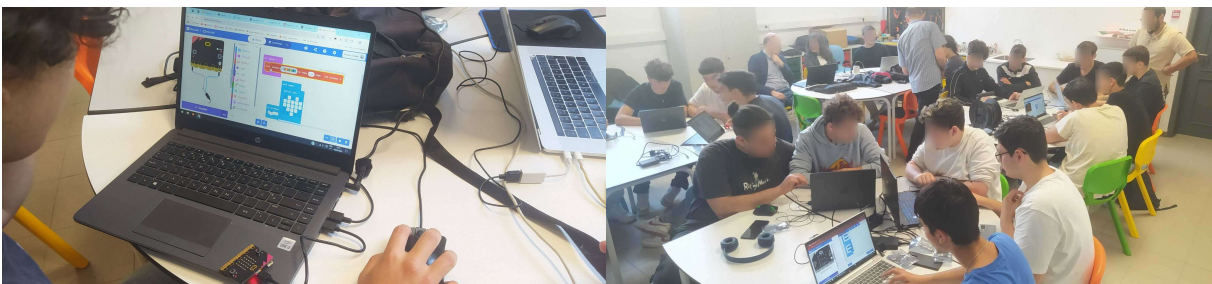


Figure 9: GEO-kit classroom implementation (Seismometer activity) with 11th grade students from ES Maria Lamas in Torres Novas, Portugal.

In Austria, the Realgymnasium Schwaz used the GEO-Kit assigned to project partner PHT to implement an earthquake-detection activity, complemented by Micro:bit sensor-technology training sessions and the creation of 3D terrain profiles with 3D printing. Map literacy and the analysis of satellite images covered key content, and the Kit-supported activities were applied to local contexts such as landslide risk, flooding, glacial retreat in the Alps, forest soil drought and pest infestations in forested areas.

In Cyprus, partners deployed Kit components in interdisciplinary learning scenarios that combined Micro:bit sensors, GPS applications and mobile data-collection tools with Google Earth, Google My Maps, ArcGIS StoryMaps, CODAP and Scratch. Activities such as “EcoTrakker: Green Route Challenge”, “When the Earth Moves: Earth Dynamics, Natural Hazards and Human Adaptation” and “Cool School Map” exercised cartography, GIS, EO/RS, coding and map storytelling in a single project.

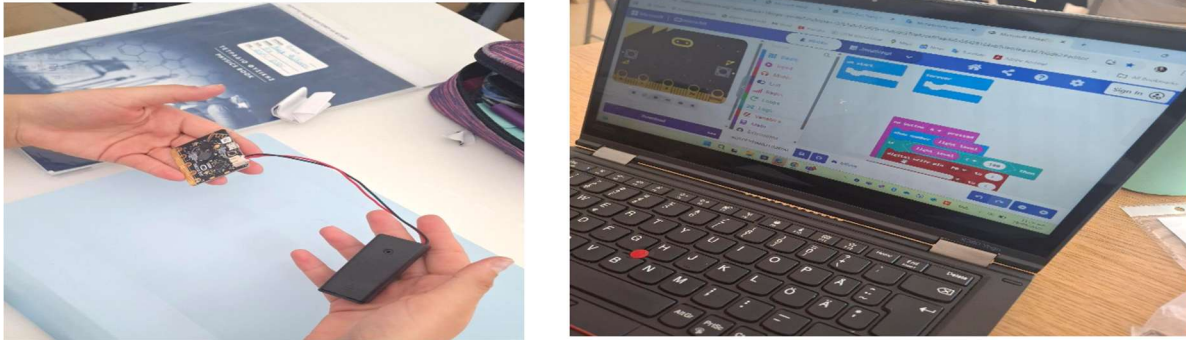


Figure 10: GEO-kit classroom implementation (Light Pollution activity using micro:bit) with 7th grade school students from Pancyprian Gymnasium of Nicosia, Cyprus.

In Greece, EA documented eleven school implementations spanning all five GEO-Concepts, including “Mapping my school yard with Arduino”, which used the Kit’s STEAM configuration directly. NTUA supported two (2) activities across junior high schools on the islands of Antiparos and Paros. The first activity, building a seismograph, used two micro:bit microcontrollers, one as a transmitter equipped with an accelerometer to detect vibrations, and the second as a receiver to display and record the data. Students learned how earthquakes propagate through tectonic plate movement, experimented with three-axis vibration detection, and used a DC motor with an eccentric cork to simulate seismic activity of consistent intensity. The project was successfully implemented in both sections of Antiparos Junior High School, six sections at Parikia Paros Junior High School, and two sections at Archilochos Junior High School, with consistently positive learning outcomes across all groups.

The second activity, Cartography and GIS Peddy Paper, introduced students to geolocation concepts by having them measure their school's basketball court using multiple methods, via the 3D Fix app for satellite data, GEO Tracker for route recording, an Arduino with a GPS NEO-6M module, and Google Earth Pro for data processing, then comparing results against a physical tape measure. Students discovered that measurements fell within acceptable GPS accuracy margins and engaged deeply with questions about signal accuracy, satellite synchronization, and spatial orientation.

The third activity, Investigating Air Quality, was used by students of Ellassona Youth in Larisa in a project to document the natural habitat of the endangered Balkan chamois species (*Rupicapra rupicapra balcanica*) in the unique ecosystem of Mount Olympus. This project

combined field observations, satellite data and youth led environmental action to explore how recent changes in climate and humidity may be affecting the habitat of the chamois. To strengthen the scientific foundation of their work, the school integrated the GEO-Kit provided by Spotin into their investigation. Students connected temperature and humidity sensors to the Micro:bit microprocessor and programmed the device to collect real-time environmental data. An initial pilot test was conducted in a controlled setting to calibrate the sensors and verify the setup before moving to the field to gather temperature and humidity measurements directly from the wild goat habitat. This project won the 1st prize in the ESERO Greece Climate Detectives 2025-2026 Competition and was selected to represent Greece at the International Climate Detectives Summit 2026 at the ESA ESRI facility in Frascati, Italy. A storymap of the project is available at <https://arcg.is/0mzHvz>.

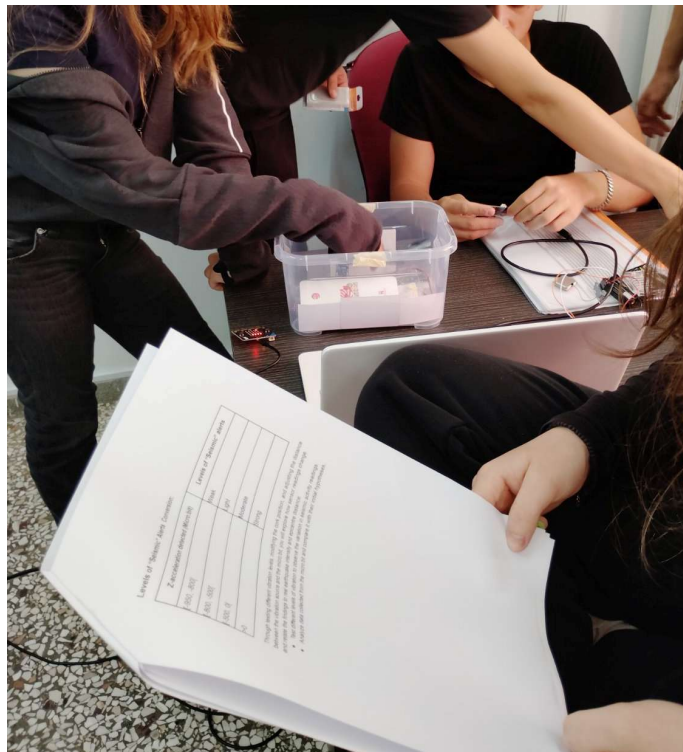


Figure 11: GEO-kit classroom implementation (Seismometer activity) students from Secondary school of Antiparos, Greece.

In Bulgaria, the PFE-led Hub focused on cartography, EO/RS and map storytelling, with Kit-supported coding activities delivered as 3-hour workshops within the National Teacher Academy.

To make the breadth of these implementations easier to assess at a glance, Tables 1 and 2 below summarise, respectively, the international and national training events that featured the GEO-Kit, and the school-level implementations documented by the national coordinators in their reporting to the consortium.

Event	Host / location	Dates	Type	Kit configuration used	GEO-Concept(s)
Summer School 2024	EA / Marathon, Greece	7–12 Jul 2024	International	STEAM/EO (full Kit, demo)	GC3, GC5
Winter School 2025	ÖWF / Vienna, Austria	10–14 Feb 2025	International	Seismometer (GC3) + Smart Lighting (GC5)	GC3, GC5
Summer School 2025	NUCLIO / Sesimbra, Portugal	Jul 2025	International	Full activity catalogue (six activities)	GC1–5
National workshops (Austria)	PHT / Tyrol	Throughout 2024–26	National (10 events)	Seismometer + sensors	GC3, GC5
“Sustainability and Citizenship” blended programme	NUCLIO + UC / Portugal	2024–25 and 2025–26	National (multi-cycle)	Seismometer + GC4/GC5 activities	GC3–5
STEAM workshops within National Teacher Academy	PFE / Bulgaria	Feb 2025, Feb 2026	National (3 h)	GC5 (entry-level)	GC5
Hub training events	CPI + EUC / Cyprus	2024–26	National (several)	Micro:bit sensing + GIS/Map Storytelling	GC1, GC4, GC5
Hub training events	EA, NTUA + SPOTIN / Greece	2024–26 (9 events)	National - Local	“Mapping my school yard with Arduino” configuration, “Building a Seismograph”, “Cartography & GIS Peddy Paper”	GC1–5, GC5

Table 1: Training events that featured the GEO-Kit during the first and second implementation cycles.

At the school level, Table 2 lists the implementations documented by the national coordinators in which the GEO-Kit was used, together with their student and teacher counts. It draws on the Training Implementation Reports collected by NUCLIO, EA, PHT, CPI/EUC and PFE for the first implementation cycle, and is restricted to activities that explicitly mobilised Kit hardware (Micro:bit, Arduino, sensors or geolocation module); the broader catalogue of school-based activities relying only on online tools is reported in D5.2.

School	Country	Activity	GEO-Concept	Students	Teachers
Realgymnasium Schwaz	Austria	Seismology / Environmental hazards / What maps can show us	GC1, GC3, GC4, GC5	95	3
Mittelschule Kematen	Austria	3D terrain profiles (Coding for Urban Sustainability)	GC5	42	1
St. Julian's	Portugal	GEO-Kit Seismometer	GC5	16	2
Escola Secundária Maria Lamas	Portugal	GEO-Kit Seismometer	GC5	16	1
Ellinogermaniki Agogi	Greece	Mapping my school yard with Arduino	GC5	115	3
Secondary school of Antiparos	Greece	GEO-Kit Seismometer, Cartography & GIS Peddy Paper	GC5	22	1
Secondary school of Parikia (Paros)	Greece	GEO-Kit Seismometer, Cartography & GIS Peddy Paper	GC5	72	2
Secondary school of Archilochos (Paros)	Greece	GEO-Kit Seismometer, Cartography & GIS Peddy Paper	GC5	19	2
Elassona Youth (Larisa)	Greece	Investigating Air Quality	GC3	n.r.	n.r.
54 School Sv. Ivan Rilski (Sofia)	Bulgaria	STEM/robotics (Kit-based)	GC5	n.r.	n.r.
134 School Dimcho Debelyanov (Sofia)	Bulgaria	Primary STEM/robotics (Kit-based)	GC5	n.r.	n.r.
CY.M.E. Summer School	Cyprus	EcoTrakker; Flying Forest Hero (Micro:bit + GIS)	GC1, GC2, GC5	93	4
Kiti Gymnasium, Larnaca	Cyprus	When the Earth Moves (Micro:bit sensors + EO/RS)	GC1, GC3	22	1
Pancyprian Gymnasium of Nicosia	Cyprus	Light Pollution (Micro:bit + GIS)	GC5	n.r.	n.r.

Table 2: School-level implementations of the GEO-Kit reported by national coordinators. "n.r." = not reported in the source implementation report.

Reading these two tables alongside the consortium-level KPIs reported in D5.2 (677 educators trained in the first implementation cycle alone) gives a sense of the multiplier effect of the Kit: a small number of physical Kits distributed through the seven National Hubs reach, through trained teachers, an order of magnitude more students than would be possible through direct consortium delivery.

5.4 Teacher Feedback and Lessons Learned

The “Trained Teachers’ Opinion” questionnaire results reported in D5.2 give an overall mean score of 4.37 out of 5 across thirteen Likert items, with the highest ratings going to clarity of objectives and to the balance between theory and hands-on work—two qualities that the Kit-supported activities deliberately maximise. The free-text feedback collected from teachers points to three recurring themes. First, the Kit’s low-cost, modular nature is consistently appreciated, particularly by teachers in schools with limited budgets. Second, the seismometer activity stands out as the single most memorable element of both the Winter School and several national workshops, both for its conceptual reach (linking a classroom device to global Earth Observation networks) and for its theatrical quality in the classroom. Third, teachers requested more advanced learning pathways for GIS, coding and map storytelling, which the consortium has committed to address through the upgraded Teachers’ Virtual Training platform and through new Kit-based activities planned for the final implementation cycle.

The first implementation cycle also surfaced operational lessons that have shaped the current version of the Kit. The DHT11 sensor proved unstable on Micro:bit v2 and has been replaced by the DHT22 throughout the air-quality and agro-climatic activities. The NEO-6M geolocation module lacks block-based libraries for the Micro:bit and is therefore deployed with the Arduino UNO (via a Keyestudio KS0297 expansion board where appropriate), which has the further pedagogical benefit of introducing students to written code in a meaningful context. The decision to use two physically separate power supplies for the sensing Micro:bit and the DC motor in the seismometer activity, rather than sharing a single supply, was confirmed by classroom experience to be essential for clean readings. Finally, technical glitches reported by students—poor internet connections and device failures rather than pedagogical shortcomings—have led the consortium to package each Kit with a standalone offline-capable activity, the seismometer, so that classroom activities can proceed even when network conditions are unfavourable.

6 Dissemination and Availability through GEOBSERVE

6.1 Hosting of GEO-Kit Resources on the GEOBSERVE Platform

The GEOBSERVE platform—accessible at <https://portal.geoacademy.eu> and developed by NUCLIO under WP4—provides the central digital home for all GEO-Kit resources produced by the consortium. The platform was designed not as a static repository, but as a **Community of Practice (CoP) infrastructure** that combines a curated catalogue of tools and resources, a teacher-facing space for sharing classroom experiences, and a back-office workflow that allows partners and registered teachers to publish their own materials.

For the GEO-Kit deliverable, GEOBSERVE hosts three categories of materials, all linked from a dedicated *GEO-Kits* entry point:

- **Activity Guides** — the full pedagogical guides for each of the six activities described in Section 4, structured around the inquiry-based 4-step cycle (Introduction → Hypothesis → Experimentation → Sharing and reflection). Each guide is published as a self-contained post under the *Resources* category and tagged with the relevant GEO-Concept(s) and competency pillars.
- **Technical References** — companion documents that provide the operational guidance required to implement each activity, including detailed instructions for the MakeCode environment, illustrated block-based programs, sensor wiring, threshold definitions, measurement protocols and recommended extensions. Technical References are released as PDF annexes to preserve the clarity of code examples, diagrams and screenshots, and to ensure ease of use during classroom implementation.
- **Supporting assets** — the GEO-Kit components list, sample datasets, lesson plan templates and evaluation rubrics that teachers can re-use and adapt.

Each resource is published following a standardized editorial workflow defined in the internal guide *How to Add a Tool or Resource on the GEOBSERVE Platform*. Posts are entered through the WordPress dashboard at portal.geoacademy.eu/wp-admin, classified under the *Tools* or *Resources* category as appropriate, and accompanied by a featured image (1200 × 630 px, with mandatory alternative text for accessibility), a short excerpt and the relevant taxonomic tags. Comments are disabled by default to keep discussion within the dedicated CoP spaces, while pingbacks and trackbacks are enabled to support cross-linking from partner websites and external dissemination channels. The *No Sidebar* layout is used for all GEO-Kit posts to ensure visual coherence with the rest of the platform.

The user model adopted for the platform organises participants into three operational groups, in line with the simplified governance approach validated by the consortium: **Authors** (partners and accredited contributors who can create courses and curated resources), **Members** (registered teachers who can submit lesson plans, classroom artefacts and resources for review) and **Users** (any visitor exploring the public catalogue). This three-tier structure keeps editorial responsibility clearly attributed while opening a low-friction contribution path to the wider teacher community. Working language for shared discussion spaces is English, while individual resources can be uploaded in any of the project languages.

6.2 Open Educational Resources and Licensing

All GEO-Kit materials hosted on GEOBSERVE are released as **Open Educational Resources (OER)**, in line with the Erasmus+ Programme Guide requirements on open access and with

NUCLIO's and the consortium's long-standing commitment to open educational practice. The default licensing scheme is **Creative Commons Attribution 4.0 International (CC BY 4.0)** for textual and graphical materials, allowing teachers across Europe and beyond to download, adapt, translate and re-share the resources, including for commercial training contexts, provided that the original authors and the GEO-Academy project are properly credited.

Where third-party content is reused—for example, illustrations of the MakeCode environment, references to the IRIS Consortium, the British Geological Survey, the U.S. Geological Survey, NASA Data Sonification, ESA *Sound of the Earth*, Eurostat, Copernicus, Our World in Data or the International Dark-Sky Association—the original licensing terms are honored and clearly attributed in the *Resources & Further Reading* appendix of each Activity Guide. Source code provided through the technical references and accompanying repositories is released under a permissive open-source license (typically MIT) to maximize classroom and developer reuse.

Three operational principles underpin the OER strategy of the deliverable:

- 1 **Findability** — every resource is indexed on GEOOBSERVE under a clear taxonomy (GEO-Concept, competency pillar, school level, language) and is discoverable via the platform's internal search and via standard search engines, including through descriptive alt-text on featured images.
- 2 **Adaptability** — Activity Guides and Technical References are released in editable formats (Markdown / DOCX / PDF) so that teachers and trainers can localise content (translation, examples, datasets), repurpose blocks of an activity for shorter lessons, or combine activities across GEO-Concepts.
- 3 **Citability** — each resource carries authorship, version, date and a stable URL on `portal.geoacademy.eu`, making it possible to cite the GEO-Kit materials in academic publications, teacher dossiers and CPD portfolios.

This OER framing ensures that the GEO-Kit resources remain useful well beyond the project lifetime, and that the European teacher community can continue to build on them through translation, adaptation and remixing.

3.1 Promotion and Community Engagement

Hosting the GEO-Kit resources on GEOOBSERVE is a necessary but not sufficient condition for impact: their value depends on active promotion and on the development of a living community of teachers who use, adapt and contribute back to the catalogue. The dissemination strategy for the GEO-Kits combines four complementary channels.

First, **the GEO-Academy National and Local Hubs** act as the primary distribution layer. Each partner country is responsible for promoting the GEO-Kit catalogue within its national teacher

network, articulating it with local CPD frameworks and existing STEAM initiatives. The Portuguese hub, coordinated by NUCLIO, has integrated the GEO-Kit materials in its ongoing teacher training calendar and uses the activities as flagship demonstrators in school visits and outreach events.

Second, **the international training events of the project** — including the Winter School in Vienna, the Summer School in Sesimbra (M26, hosted by NUCLIO) and the closing conference in France (M35) — provide concentrated, high-visibility moments for teachers to experience the GEO-Kits in person, receive direct guidance from the authors and bring back ready-to-use materials to their schools. Each event closes with a pointer to the corresponding GEOOBSERVE resource pages, supporting the transition from face-to-face training to ongoing online use.

Third, **the GEO-Academy communication channels** — the project website, the newsletter (eight editions published over the project lifetime), the partners' social media channels and the Erasmus+ Project Results Platform — are systematically used to announce new resources, highlight teacher contributions and share short success stories. Featured images and excerpts are designed to render correctly on social media (1200 × 630 px landscape format) so that resources travel well outside the platform.

Fourth, **the GEO-kit Hackathons, webinars**, and other community-engagement initiatives create concrete pretexts for teachers and students to use GEO-Kit activities, produce shareable artefacts and submit them through the platform. Each contribution that meets the quality bar is itself published on GEOOBSERVE, feeding a virtuous cycle in which the catalogue grows beyond the original consortium output and progressively becomes a teacher-curated resource.

Together, these four channels are designed to maximise reach during the project, but also to seed the conditions for **long-term sustainability** of the GEOOBSERVE Community of Practice — a topic developed further in Section 7.

4 Sustainability and Future Use

4.1 Replicability and Scalability of the GEO-Kits

The Kit has been designed from the outset to be reproducible by any school willing to invest a modest budget. All components are commercially available from common educational suppliers, and the activities can be delivered with a sub-set of the components if needed — for example, the seismometer activity requires only two Micro:bit boards, a small DC motor, batteries and a cork. The published bill of materials, wiring diagrams and code samples on GEOOBSERVE make it straightforward for a school to assemble an additional Kit using locally sourced parts. National coordinators report that, in several cases, schools have begun

assembling additional Kits with their own funds after observing the original Kit in use during a workshop.

4.2 Cost and Procurement Considerations

The full Kit configuration described in this deliverable can typically be assembled for a few tens of euros per unit, depending on the specific suppliers and on whether the school already owns Micro:bit boards or Arduino boards (which are increasingly common in European secondary schools). This low cost is by design, since one of the requirements of Task 4.4 was to keep the financial barrier as low as possible, especially for the seven national hubs and their school networks. NUCLIO maintains a reference supplier list on GEOBSERVE, regularly checked against availability and price, to help interested schools obtain components without having to engage in lengthy market research.

4.3 Beyond the Project: Long-term Use in Schools

In each of the consortium countries, an exit strategy has been articulated to ensure that the Kits and the associated activities continue to be used after the formal end of the project in May 2026. The strategy combines three elements: institutional anchoring (the Kits remain hosted in the National GEO-Hubs, which are typically embedded in universities or pedagogical institutes that will outlive the project); a teacher-ambassador network (trained teachers from the Summer and Winter Schools serve as multipliers within their schools and regional networks); and an active online community on GEOBSERVE, committed to remain freely accessible after the project's end as part of the GEO-Academy legacy. Together, these mechanisms aim to convert what began as a project deliverable into a durable educational resource embedded in the everyday practice of European schools.

5 Conclusions

The GEO-Kit and the associated activity catalogue described in this deliverable constitute one of the central operational outcomes of Work Package 4 of the GEO-Academy project. Developed under Task 4.4 and complementary to the GEOBSERVE platform (D4.2) and the National and School Community GEO-Hubs (D4.1), the Kit translates the GEO-Labs vision into a concrete classroom reality, offering teachers and pupils a low-cost, modular and pedagogically versatile entry point into geospatial science, Earth Observation, robotics and coding.

Across all five GEO-Concepts and the three GEO-Academy competency pillars, the same set of components is redeployed in six complementary activities —from the flagship Micro:bit seismometer to agro-climatic monitoring, smart lighting, air-quality investigation, Peddy Paper map literacy and the sonification of geospatial data— demonstrating that meaningful integration of digital, green and spatial skills does not require expensive equipment but rather a careful pedagogical design that connects sensor data to authentic place-based questions. Pilot implementations across Austria, Bulgaria, Cyprus, France, Greece, Portugal and Sweden,

anchored in the three International Development Courses (Marathon 2024, Vienna 2025, Sesimbra 2025) and in a dense national training programme, have confirmed the relevance, replicability and pedagogical reach of the Kit.

With its accompanying Activity Guides and Technical References openly published on GEOBSERVE under CC BY 4.0, with the supporting infrastructure of the seven National Hubs, and with the teacher-ambassador network that has grown out of the International Schools, the GEO-Kit is well positioned to outlive the formal end of the project and to continue serving the European teacher community well beyond 2026.

Annexes

Annex 1. Bill of Materials and Reference Configurations

The Bill of Materials presented in Table 3 lists all components included in the full GEO-Kit configuration, with the typical quantities and indicative unit prices observed in mid-2025 from European educational suppliers. The list is illustrative rather than prescriptive: equivalent components from alternative suppliers are acceptable, and several subsets of the table can be assembled into the GC-specific configurations described in Section 3.4. A regularly updated supplier list is maintained on the GEOBSERVE platform under the GEO-Kits resource page.

#	Component	Quantity	Typical unit price (EUR)	Used in
1	BBC Micro:bit v2	2	20–25	All activities; sender/receiver in 4.2
2	Arduino UNO R3 (or compatible)	1	15–25	4.3, 4.4, 4.6 (precision sensing)
3	DHT22 temperature and humidity sensor	1	5–8	4.3, 4.6
4	BME280 sensor (T / RH / P)	1	5–10	Extended 4.6
5	MQ-135 air-quality sensor (gases)	1	3–6	4.3
6	Dust sensor (Waveshare or equivalent)	1	10–15	4.3
7	NEO-6M GPS / geolocation module	1	8–12	4.4 (Peddy Paper); outdoor logging
8	Keystudio KS0297 Micro:bit expansion board	1	8–12	4.4
9	DC motor (small, hobby grade)	1	2–5	4.2
10	Bottle cork (offset weight on motor shaft)	1	~0	4.2
11	Battery pack for Micro:bit (2 × AA, with on/off)	2	2–4	4.2, 4.3, outdoor use
12	Battery pack for DC motor (2 × AA)	1	2–4	4.2
13	AA batteries	8	0.5–1 each	all powered configurations
14	USB micro-B to USB type-A cable	1	2–4	Micro:bit–PC link
15	Breadboard (half size)	1	2–4	4.3, 4.6, 4.7
16	Jumper-wire set (male-male, male-female)	1 set	3–6	all wired sensors

17	SD-card shield for Arduino + SD card	1	6–10	Extended logging (3.2 / 4.6)
18	External LED (5 mm) + 220 Ω resistor	1	~0.5	4.7 (optional)
19	PIR motion sensor	1	3–5	4.7 (advanced extension)
Total	Indicative full Kit	—	~ 100–150 EUR	—

Table 3: Indicative Bill of Materials for one full GEO-Kit (mid-2025 European educational suppliers, prices excluding VAT and shipping). The full configuration is sized for a single classroom team; schools typically operate 3–6 Kits in parallel.

At the indicative range of 100–150 EUR per Kit, a school equipping a single classroom of 24 students with six parallel Kits would invest approximately 600–900 EUR in hardware, in addition to existing classroom computers and broadband access. Where Micro:bit boards or Arduino boards are already available in the school (which is increasingly the case in European secondary schools), the marginal cost of adding the geo-specific sensors and accessories falls to roughly half of the figures above. This budget profile is in line with one of the core requirements of Task 4.4 in the Grant Agreement: to keep the financial barrier as low as possible so that the seven National Hubs and their school networks can sustain the Kit beyond the project.