Digital Fabrication and Maker Movement in Education
Making Computer – supported Artefacts from Scratch

Deliverable D5.1

Pilot Protocol

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EXECUTIVE SUMMARY

This deliverable reports the first implementation of activities required to run pilots, including space structuring, equipment establishment and integration of the eCraft2Learn learning ecosystem, in the selected pilot sites. This task includes the realization and the equipment setup of the labs in order to enable the full operation of the eCraft2Learn learning ecosystem. The 4 pilot sites are: a secondary school in Athens and the Technopolis City of Athens (GR), a secondary school in Joensuu and the Joensuu Science Park (FI). The overall setup is based on hardware and software tools and specific directions described in WP4 (D4.2) as well as on technically and pedagogically sensitive studies and information provided by WP3 (D3.2, D3.3 and D3.4). The work and guidelines provided by the deliverable D5.1 are reflecting the first co-created implementation of the eCraft2Learn ecosystem and so, further useful feedback and revisions are expected to follow. The data to be collected from the pilots will serve as the basis for further improvement of the implemented craft- and project-based pedagogical tools and technical foundation.

1 INTRODUCTION

In the last years, we are witnessing an increased development and spread of technologies that have radically changed the way people live and work. Scholastic institutions in Europe have been, albeit slowly, partly involved in this phenomenon, to the interest of institutions that support this through specific financial assistance for research projects on these topics. The recent literature highlights a wide set of projects aiming in documenting and evaluating the impact of the ICT (Information and Communications Technologies) employment in education (Unesco 2005).

However, despite the abovementioned positive effects, the spread of ICT within school environments and the increasing pressure of the institutions towards the authorities, the educational system is not yet able to efficiently integrate ICT into curriculum paths to improve the cognitive skills of the students. This fact has been exemplified in a report of the European Commission, stating, “the challenge is not the lack of technology in schools but the huge variation of using technology meaningfully in education” (European Commission 2013). In fact, new technologies are simply used to reinforce the old ways of teaching – an ineffective approach in today's society, where school kids will be likely called to take jobs that have not been invented yet (Fullan & Langworthy, 2013). This consideration takes an important implication, especially today, given the youth unemployment challenge that Europe is facing.

In this document, we present in detail, the first implementation of preparatory activities required to run the eCraft2Learn project pilots, including teacher training, space structuring, equipment establishment and integration of the eCraft2Learn learning ecosystem in four selected pilot sites. More specifically, based on the selected hardware equipment (i.e., 3D printers, Arduino (https://www.arduino.cc/) and Raspberry Pi (https://www.raspberrypi.org/) boards and by exploiting effective pedagogical practices, we will provide methods to train teachers and students effectively as well as to assist students of different skills and characteristics to do great work of lasting value.

1.1. THE ECRAFT2LEARN LEARNING INTERVENTION

The eCraft2Learn ecosystem is based on a craft- and project-based pedagogy. This pedagogy derives from inquiry-based learning methods and has expanded to include both the knowledge and the specific end-product that needs to be created through design thinking.

1.2. TIME PLAN IN THE CONCEPT OF ITERATIVE PHASES

Pilots will be developed iteratively with the involvement of the target groups, starting with the first prototype of the eCraft2Learn learning ecosystem. The prototype will be refined based on the practical experiences obtained by the participant groups of students and teachers. Two types of demonstrators -within formal and informal educational settings- are developed to be used by two user groups (secondary school students in Finland and Greece).

The first period of pilot organization and implementation of the learning activities in school and informal educational settings is planned for M10 to M13, while the second one, after the necessary feedback has been collected, processed and implemented, is planned for M18 to M21. In both cases of learning activities with students, a preparatory training for their teachers/educators stage needs to precede on M9 and M17, respectively.

The earlier stages of the training period should be organised in a way that lets students achieve fast and encouraging results, thus allowing deeper engagement and more complicated approaches during later stages.

1.3. The eCraft2Learn educational projects

In the context of the eCraft2Learn project, students of different skills and preferences will cooperate (in teams) in order to proceed with their work. The Constructivist "learning by making" methodology is strongly related to the do-it-yourself (DIY) philosophy, which stands for learning that goes beyond knowledge acquisition and aims to support future generations of empowered citizens (Meyer and Fourie, 2015), and is the driving force behind the eCraft2Learn pedagogy.

The project activities during the pilots are designed so as to explore unique making tools to support a learning ecosystem for attracting and keeping learners interested and motivated, with hands-on and meaningful learning activities. Working within small zones of such an ecosystem, studies have reported the potential impact on learners, both in subject areas (Physics, Electronics, Mathematics, Engineering, Computer science and more) and on their personal development including cognitive, meta-cognitive and social skills (Geier et al., 2008; Mioduser & Betzer, 2007). Therefore, learning by making (Papert&Harel, 1991) is a very effective pedagogical tool to develop critical thinking and project-solving skills in the real world, a concept also referred to as critical making (Ratto and Boler, 2014).

Further details on how the project activities are organized within the pilots are provided in section 4 of this document deliverable.

2 Setting Up the eCraft2Learn lab

In this section, the basic components (in terms of hardware and software) of each pilot site are briefly explained. Furthermore, several practical issues, like fundamental safety and ergonomics, are highlighted, so that all the activities may run flawlessly.

2.1. Hardware anatomy of the eCraft2Learn learning ecosystem

In order to have a clear view of the hardware components of the eCraft2Learn ecosystem, some information is briefly presented; details are in the deliverable D4.2 (part of the WP4).

Given the above, the first implementation of the hardware core of the eCraft2Learn ecosystem will include:

- A set of Raspberry Pi 3 (RPi3) units, serving as experimental development computers (workstation units) for the students. These units are equipped with TFT screens and keyboard-mouse sets. The adoption of this solution tackles the problems related to the vast software and hardware diversity characterizing a typical School Lab and reduces the Lab's overall energy consumption
- A second optional set of Raspberry Pi 3 (RPi3) units that can be used for the potential implementation of the designed artefacts (the more complex ones).
- One or more Arduino boards connected with a variety of electronic components and/or the Raspberry Pi 3 units. These Arduino boards will be the core module inside the majority of the designed artefacts
- Various DIY electronic components (e.g. photoresistors, potentiometers, servomotors, LEDs) that will be used in conjunction with the RPi3 and the Arduino units to implement the designed artefacts
- Various DIY modified parts brought from home during a recycling process, like broken toys, plastic bottles, pieces of paperboard, computer fans, speakers, etc.
- Optionally, some tablet and/or smart phone devices (preferably tablets) are intended to interact remotely with the artefacts to be implemented.
- A Raspberry Pi unit (or a conventional PC) to act as 3D printing server, a potential file and/or web server. This unit will run the appropriate 3D printing software.
- A 3D printer used for preparing customised physical components integrated in the creation-programming-sharing workflow. This integration represents another innovative aspect of the eCraft2Learn action.
- Some extra networking equipment to facilitate the interconnection of the pilot sites (eCraft2Learn ecosystem islands) and provide further access to the Internet and project's resources.
- The necessary power supply equipment like power banks, small solar panels, electricity mains.

In the following subsections, the most critical of the above-mentioned hardware components are further discussed.

2.1.1. ARDUINO

The eCraft2Learn Raspberry Pi device that is used as a desktop computer, will be used to communicate with external devices. In most cases, these external devices will be Arduino Uno boards that are used to implement computer supported artefacts. The user can program, monitor and communicate with the Arduino Uno boards of these artefacts directly from the RP3 device.

The Arduino hardware to be used -as suggested in version 1 of the platform- will be the popular Arduino Uno board. The Uno has both digital and analogue pins that allow users to control actuators such as LEDs, Piezo components, servo motors, DC motors, and the PWM technique provides some pins with the possibility to fade LED's, custom control DC motors, vibrators, etc. Input components used can be everything from simple digital buttons to temperature sensors, light sensors, proximity sensors, motion sensors, variable resistors (such as potentiometers, flex sensors, pressure sensors, etc.) to sensors that are tied to other communication protocols.

2.1.2. RASPBERRY PI (RPI)

Raspberry Pi (https://www.raspberrypi.org/) is a low cost, credit card sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse. It is a powerful small-sized device that enables people of all ages explore computing and learn how to program in languages such as Scratch and Python. It is effective in doing everything you would expect a desktop computer to do, from browsing the internet and playing high-definition videos to making spreadsheets, word-processing, and playing games. Furthermore, the Raspberry Pi has the ability to interact with the outside world, and has been used in a wide range of digital maker projects, from music machines and parent detectors to weather stations and tweeting birdhouses with infrared cameras.

The wide adoption of RPi3 and the large variety of examples available will inspire the student in the **ideation** stage and will engage them in **sharing** their artefacts with the rest of the world. Indeed, the RPi3 units can be used as conventional workstation units to program the artefacts or they can be the core unit inside several cases of artefacts' construction. All the necessary software components will be hosted (or accessed) via the microSD card of the RPi3 units. For this reason, this microSD card can be seen as one of the most critical core components of the eCraft2Learn ecosystem.

2.1.3. 3D PRINTERS

The making of the artefacts will be facilitated with 3D printing technology. Specifically, the Ultimaker 2+ and Ultimaker 3 3D printers (https://ultimaker.com/).

Ultimaker 2+

Currently, this is the most popular choice of Ultimaker 3D printer for schools, as it is an all-around professional desktop 3D printer of great value that delivers consistent results. Engineered to perform, the Ultimaker 2+ is reliable, efficient, and user-friendly. With a simple display and control dial, even very young students -with a little prior instruction- can operate this printer independently.

Ultimaker 3

The Ultimaker 3 is the most reliable dual extrusion 3D printer available, allowing students to print models in two colours or materials without pausing the print. This professional desktop printer allows prints with more complex geometries to be created by using dissolvable PVA for printing the support structures. This provides greater opportunities for students to realise more complex designs.

2.1.4. DIY Electronics Components

We are referring to simple components, like connector cables, breadboards, photoresistors, potentiometers, servomotors and LEDs, which can be used in conjunction with the RPi3 and the Arduino units, to implement the designed artefacts. These DIY electronics components in conjunction with the RPi3 and the Arduino units and 3D printed parts, can cause a significant change in how we learn.

Indeed, whereas software has already become increasingly more accessible to a broader audience, this is not always the case for hardware, where complexity and high costs of materials have been considerable barriers to learning. The eCraft2Learn project recognises the potential in digital fabrication and making DIY technologies: if coupled with proper learning methodologies such as learning by making, these technologies can provide learning experiences that promote young people’s creativity, critical thinking, teamwork, and problem solving; skills that are essential in the workplace of the 21st century. Hence, the 21st century learning ecosystem should be designed in a way where students are actively engaged with learning tasks, hands-on activities and with each other.

2.2. Software anatomy of the eCraft2Learn learning ecosystem

In order to have a clear view of the hardware components of the eCraft2Learn ecosystem, some information is briefly presented; details are in the deliverable D4.2 (part of the WP4).

A unified user interface (UUI)has been designedto bring together the proposed software tools that the eCraft2Learn ecosystem builds upon; more details about the UUI are provided in section 2.3. The basic software tools are described in the list below:

- The ‘native’ Arduino SDK (IDE, compiler and library). Although it's true that software tools seem to privilege a block-based orientation, considered more suitable for rapid prototyping and in terms of usability, the Arduino SDK (and the wiring language it is using) is somehow the basis of Arduino programming and in many cases a prerequisite software package for many other visual programming tools.
- Visual Tools like the MIT Scratch (https://scratch.mit.edu/) and additional components such as the Scratch GPIO for using the General Purpose Input/Output pins (GPIO) that the RPi3 natively has or the Scratch4Arduino (http://s4a.cat/).
- The Ardublock tool (http://blog.ardublock.com/engetting-started-ardublockzhardublock) that works as a component of the Arduino SDK and offers the capability of visual programming of an Arduino unit in a stand-alone way. If creating minimalistic artefacts of high autonomy is a priority, this tool will be a necessary asset. This option is offered by other

tools as well, but, at the moment of writing this document, Ardublock is offering a mature and stable set of blocks for visual programming the Arduino a stand-alone way.

- The visual programming toolSnap! and its extension, Snap4Arduino (http://snap4arduino.rocks/), that allows RPi3 - Arduino interoperation, custom visual block creation, provides easily exportable/importable .xml code and cooperates with many web based tools for useful data exchange.
- Visual programming capabilities of Pocket Code and/or MIT App Inventor (http://appinventor.mit.edu/explore/) tools should be usedto program tablets and/or smart phones so as to interact with Arduino or RPi3 units, via Bluetooth or WiFi interfaces.
- Simple necessary code blocks (most) in Python implementing server functionality (e.g. GPIO specific or web specific) on RPi3 units and thus facilitating the interaction with the artifacts.
- 3D printing software allowing the design of models to be printed like the FreeCAD(https://www.freecadweb.org/) or the web based Tinkercad(https://www.tinkercad.com/).
- 3D printing software for the machine acting as manager of the printer like the Cura(https://ultimaker.com/en/products/cura-software) or the Octoprint/Octopi combination (https://octopi.octoprint.org/).
- Generic purpose software packages allowing actions like file sharing (WinSCP or FilleZilla), remote access (puTTY, VNC), web support, etc.

According to the SWOT analysis in D4.1, the software tools selected for the eCraft2Learn ecosystem meet most of the following characteristics:

- they can run on a RPi3 environment,
- present a reduced need of installation or update of software elements,
- have a user friendly interface,
- are pedagogically meaningful,
- are easy to integrate with the external hardware,
- are open source and free (or at least low cost) and, finally,
- are preferably capable of supporting our planned extensions such as access to AI cloud services.

A basic set of software tools will be integrated with the other parts of the eCraft2Learn technical core (i.e., UUI, educational extensions, learning analytics, etc.). Through the UUI the students will receive support to implement their artefacts in order to better fit to the diversity of skills and preferences, to better feed their creativity and to encourage their freedom to design and construct. The later pedagogically meaningful goal can be seen as a real life rule where more than one approach, tailored for different idiosyncrasies, can lead to a satisfactory result.

This basic set of software tools is extendible with more tools dedicated to more advanced users. All the necessary software components will be hosted (or accessed) via the microSD card of the RPi3 units. For this reason, this microSD card can be seen as one of the most critical core components of the eCraft2Learn ecosystem.

2.3. Unified User Interface (UUI)

The concept of the UUI tackles the need of learners and teachers to interact with the eCraft2Learn ecosystem. The educational extension of the UUI also provides services for infrastructure analytics being collected. Resources like code or data can be retrieved using the cloud support. The RPi3 units are playing a principal role, supporting the hardware needs hosting the "bouquet" of software tools (or methods to access them) in its microSD card. Indeed, all the necessary software components will be hosted (or accessed) via the microSD card of the RPi3 units. As already mentioned, this microSD card can be seen as one of the most critical core components of the eCraft2Learn ecosystem.

All necessary resources like programming environments, coding examples, designs to print, information on hardware components or shared data can be found/updated/shared via tools with which this microSD card is equipped, if not already installed on it. By this way, full access to cloud (local or remote) resources is possible. All the pilot sites implementing the pilots of the eCraft2Learn ecosystem can be seen as a whole, due to this design. Furthermore, it must be noted that the RPi 3 unit has the ability to host web server engines like Apache (https://httpd.apache.org/) and to support communication with file sharing tools like the WinSCP application (https://winscp.net/eng/docs/introduction) or the FileZilla (https://filezilla-project.org/). A separate RPi3 unit could be dedicated to these tasks assisting in educational resources sharing, mainly locally, at early lab site deployment level.

Furthermore, the UUI is web-based designed and implemented as a dashboard where users might easily add or remove components. The developed UUI is a central section where learning contents are available to learners. The interface distinguishes between the coach/teacher's and students' interactions with the system. The dashboard (Figure 2) contains folders, lessons, and events created by teachers. These modules can be resized, moved and closed. Clicking on lessons switches the view from the dashboard to the "desktop", which is normally used to operate apps (docs, pdf, etc.). Double-Clicking on folders opens up the folder in the desktop view for easier navigation. Clicking on a file from the dashboard opens up that file in the desktop view. Entries can be removed from the dashboard by clicking on the [x] next to them. We also worked on the concept that students can access default management and planning tools. Clicking on a calendar entry opens the calendar app at the selected entry in the desktop view. The calendar module in the dashboard can be resized to show more entries at once. On the side of the UUI we had our toolkit section, where students and coaches can choose among various tools. This initial interface design draft will be further evaluated with some users to understand the usability and user experience.

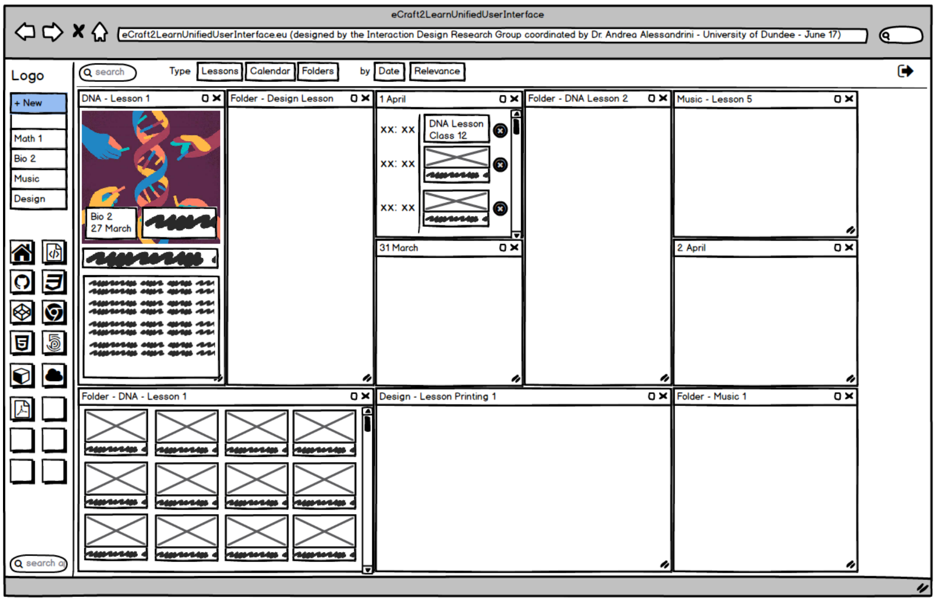

Figure 1. The eCraft2Learn Unified User Interface Conceptual View

The UUI is the main hub for using the eCraft2Learn ecosystem. Through the UUI, it will be possible to access all the tools that are used in the five stages of the eCraft2Learn environment. Figure 3 shows an indicative layout of the start screen in UUI. Each tile on the page represents a tool. The tiles are grouped in five different categories based on the five stages of the eCraft2Learn pedagogical cycle.

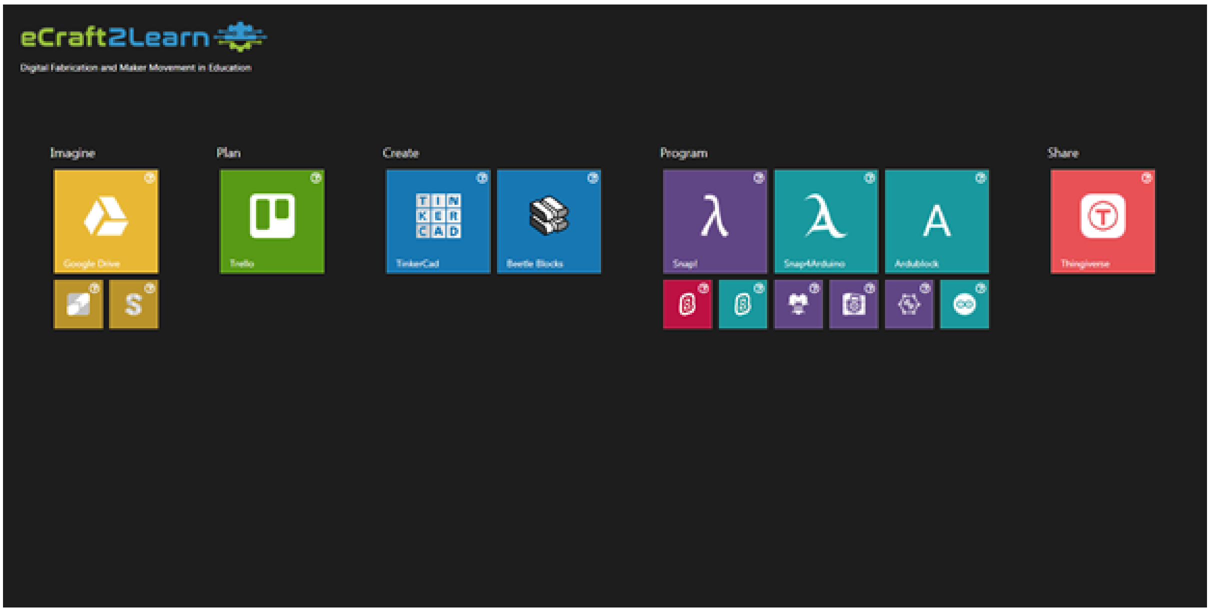

Figure 2. Indicative Layout of the unified user interface according to work of T4.5

At the backstage of UUI there is also a learning analytics engine to assess and monitor the learning process of the students. The purpose of learning analytics in the eCraft2Learn ecosystem is to provide automated tools to assist learners and instructors in the five stages pedagogical process. The analytics methods use well-known educational data mining (EDM) techniques to provide both retrospective and real-time analysis in order to support the learning and instruction process within the eCraft2Learn ecosystem. Different parts of the ecosystem (hardware and software solutions as described in this document) produce data that are analysed through a separate analytics engine (that is, the analytics engine is not part of the front-end Unified User Interface).

The analytics environment is an independent platform, implemented as a browser-based service with HTML5 and JavaScript. EDM algorithms -as part of the tool- can handle a variety of data types and formats. The data mining process is open and exposed to the users as much as possible, and the users are also given tools to affect the process, for example by selecting what data items are relevant in a particular process, what kind of time frames are used in sequential analysis, etc. The environment provides suitable EDM tools for each part of the eCraft2Learn process and visualizations aim to support the teachers' pedagogical understanding of the learning process within the digital eCraft2Learn environment (UUI) as well as possible.

2.4. KEY REQUIREMENTS - SPACE STRUCTURING CONSIDERATIONS AND SAFETY RULES

The flawless setup of the pilot sites is accomplished by a set of rules ensuring that every activity will be carried out at the maximum safety level.

2.4.1. ERGONOMIC ISSUES

The space to use for the deployment of the eCraft2Learn ecosystem should be easily accessible by both the young students and their trainers and should meet the necessary criteria in terms of ergonomics. According to the initial plan, a number of around 30 children, 10 trainers and 2 or 3 persons from the consortium -about 43 persons in total- should share the space. These numbers of people, along with the equipment, need sufficient space so as to sort the equipment in a really efficient way. According to the plan, ten teams of three children will be formed and so 10 benches are needed. In addition to that, the only 3D printer of the laboratory has to be put on a different bench. Depending on the equipment that will be used for personal computing, DIY electronics and 3D printing a bench of the size of 1.5 metres x 1.5m metres is enough both for the students' team and the 3D Printer. Furthermore, at least 40 chairs are needed for people that will be in the laboratory.

Regarding the wiring needs of each table, a socket strip of at least five safe sockets is needed for each bench. The socket strip should be fastened on the bench firmly, on a place of the table where it is comfortable to attach an equipment and safe to avoid unintentional touch. The cable of each socket strip should cross the laboratory, from the power socket to the bench, crossing a safe path. This ensures that children and teachers will not stumble on them.

One of the very important aspects of each laboratory is the laboratory light. Adequate light in the lab space is needed, preferably natural but for dark days can also be supported by artificial lighting. Visual comfort is characterized by three quantitative and qualitative features which are the basic lighting control criteria in classrooms and laboratories. The amount of light in a laboratory reaching the working level must be up to 540 lux. Furthermore, distribution of light in the workplace should be uniform on all benches. Uniform lighting is achieved by lights that open on both sides. Light curtains will help to avoid any glare, created by sunlight or intense shadows, in the place.

Regarding the ergonomic issues of the laboratory some safety issues should be taken into account. Firstly the 3D printer's bench should be put on a place that has adequate air extraction. There are research findings about 3D printer of potentially hazardous fumes. The room with the 3D printer should be well ventilated or the printer will be an enclosed printer with a vent, particularly while printing with ABS, nylon and similar materials. Those plastics tends to emit styrene, a possible carcinogen, at levels much higher than recommended by California's Office of Environmental Health Hazard Assessment (OEHHA - https://oehha.ca.gov/). However, PLA users do not have much to worry. Printing with that plastic tends to produce a substance called lactide, which is considered to be non-toxic. Finally yet importantly, a special part of the room can be formed properly as a relaxation place for students out of the main laboratory.

The laboratory is full of electronic and electric equipment, thus the room should have some proper extinguishers to encounter an eventual fire arising from an electricity problem or any other type of fire. The teachers and adults that are in the laboratory should know how to use the fire extinguishing equipment. In addition to that, the benches, tools or any other furniture should be placed properly so that they do not stand as obstacles in the case of an emergency, such as a fire or earthquake. Additionally, it is recommended to sketch a plan of the laboratory evacuation in case of an emergency. Finally, a first aid box is needed for the laboratory with all proper medical equipment, including burns ointment.

2.4.2. Wiring the various components

Two kinds of wire connection actions are necessary in order for the laboratory to operate and the artefacts to work.

The first one tackles with power supply and interconnection issues of the fundamental components of the lab, like the 3D printer, the Raspberry Pi based workstations or their screens. For this case, typical lab wiring regulations are followed, as no remarkable electric currents are expected. Furthermore, the power supply needs of the Raspberry Pi units that are acting as workstations, can be covered by the USB ports of the accompanying TFT monitors.

The second one tackles with powering up and interconnecting the artefact themselves. For this case, power supply units of power banks (having USB plug) can be used. An even better solution is to use solar panels assisted by power banks so as to highlight autonomy and environmental friendliness issues. The use of conventional batteries (e.g. the LiPo type, like the mobile phone batteries) should be avoided -especially those that have uninsulated terminals- as they are unprotected against the risk of short circuit. All the other wire connections that are necessary so that all parts of an artefact are interoperable (signal wire connections) should be done in a way that does not damage the electronic components or humans. Luckily, the current values for several signals propagating between these components are very low (in the order of a few mA) and thus cannot be hazardous for humans. On the other hand, students or teachers should avoid touching the components' pins with bare hands and they should touch quite often a grounded metallic object that they should be able to find nearby, in the pilot lab.

2.4.3. 3D PRINTING RELATED MEASURES

The materials being fed into the machine (feedstock) can have inherent hazards and may release vapours and gases that may be even more hazardous, for example, after they are heated during the 3D printing process. In the laboratory, we have to meticulously take into account the Review safety data sheets for feedstock materials, before using them. The 3D printing equipment is designed to use specific types of materials. The most common type of desktop 3D printer technology joins thin strands or filaments, made by ABS (Acrylonitrile Butadiene Styrene) or compostable materials, such as PLA, biodegradable thermoplastic aliphatic polyester derived from corn starch tapioca. Using a computer-generated image, a 3D printer heats and melts the filament, placing layers of it on top of one another to form a precise 3D replica of the image.

A NIOSH Research Rounds publication recently published a study that discusses health and safety considerations when working around 3D printers (http://www.uvm.edu/safety/shop/3d-printer-safety). Particle emissions are the focus, especially when multiple printers are running simultaneously. Another consideration is toxic vapours that can be generated by heating plastics. Safety recommendations include the following:

Use 3D printers ONLY in properly ventilated areas.

- Task ventilation may be useful for some styles of 3D printers.
- Choose low-emitting printers and feed materials/filament when possible.
- Wear proper personal protective equipment. Have a risk assessment to determine what is required.
- Purchase and use the manufacturer’s supplied controls, such as an interlocked enclosure. (Enclosures appear to be more effective in controlling emissions than a simple machine cover is).
- Maintain a safe distance from the printer to minimize the inhalation of emitted particles.
- Turn off the printer if the printer nozzle jams and allow the printer to ventilate before removing the cover.

3D printers are ideally located in a room that has additional ventilation. The heating of some thermoplastic filament can generate toxic vapours as well as vapours with high volatile organic compounds (VOCs). Most 3D printers do not come with an enclosure, exhaust ventilation or any filters. The following should be assessed before purchasing and installing a 3D printer:

- Building/Room where the 3D printer will be located
- Installation of the 3D printer in the space itself

- Selection of printing feedstock

According to the MIT, the basic 3D printing rules and safety instructions are the following:

1. Safety Equipment
2. Safety Glasses
3. Gloves (recommended for post processing)

Hazards

1. Extruder and motors are HOT during operation
2. Extruder and motors may be HOT at any time
3. PINCH POINTS while machine is moving
4. Removal tools are SHARP

Dos

1. Do clean up after, yourself
2. Do inform a mentor of machine errors or damage
3. Do inform a mentor of missing tools or supplies
4. Do ask a mentor if you have any questions or concerns
5. Do exercise caution when using cleaning tools

Don'ts

1. Don't use the printers unless you have been trained to
2. Don't attempt to modify or fix a printer without mentor approval
3. Don't let 3D printing become lazy engineering!

Ultimaker 3D printers are designed and built for fused deposition modelling for various high-quality plastics like PLA, ABS, CPE within a commercial/business environment. The mixture of precision and speed makes the Ultimaker 3D printers the perfect machines for concept models, functional prototypes and also the production of small series. Although we achieved a very high standard in the reproduction of 3D models with the use of Cura, the user remains responsible to qualify and validate the application of the printed object for its intended use. While being an open filament platform, the best results will be achieved with Ultimaker certified filament, while effort has been made in order to match material properties with machine settings (https://ultimaker.com/).

The Ultimaker 3 or Ultimaker 3 Extended generate high temperatures and have hot moving parts that can cause injury. Never reach inside of the Ultimaker 3 or Ultimaker 3 Extended while they are in an operating mode. Always control the printer with the button at the front or the power switch at the back. Allow the Ultimaker 3 or Ultimaker 3 Extended to cool down for 5 minutes before reaching inside. Do not change or adjust anything on the Ultimaker 3 unless the change is authorized by the manufacturer. Do not store items in the Ultimaker 3 (https://ultimaker.com/).

The Ultimaker 3 or Ultimaker 3 Extended is not intended for use by persons with reduced physical and/or mental abilities or lack of experience and knowledge, unless they have been given supervision or instruction regarding the use of the appliance by a person responsible for their safety. Children should be under constant supervision when using the printer (https://ultimaker.com/).

Regarding mechanical safety, as long as the Ultimaker 3 contains moving parts, no damage to the user will be expected from the drive belts. The force of the build plate is big enough to give some damage, so keep hands out of the reach of the build plate during operation. Always unplug the printer before doing maintenance or modifications (https://ultimaker.com/).

FurthermoreUltimaker 2 3D printer is a class A product. In a domestic environment, this product may cause radio interference in which case the user may be required to take adequate measures. The Ultimaker 2 can -in very rare cases- temporarily loose its display function caused by ESD. The display function can be fully restored by turning the machine off and then on again. The Ultimaker 2 contains many moving parts but the stepper motors do not have enough power to cause serious injuries and moving gears are covered. Still, it is advised to reach in the machine only when it is turned off (https://ultimaker.com/).

Furthermore, a 3D printer is an equipment that uses heat and has high risk of burns. There is a potential risk of burns: the print head can reach temperatures of up to 280 °C, while the heated bed can reach temperatures of 100 °C. Don't touch neither of those with bare hands. Always allow the printer to cool down for 30 minutes before performing maintenance or modification (https://ultimaker.com/).

General Health and Safety issues for the Ultimaker 3 and 2 is designed for Ultimaker PLA, Ultimaker ABS, Ultimaker CPE, Ultimaker Nylon and Ultimaker PVA. The materials can be printed safely if the recommended temperatures and settings are used. Ultimaker recommends printing all Ultimaker materials in a well-ventilated area and also check the SDS of each specific material for more information (https://ultimaker.com/).

Non-Ultimaker materials could release VOC's (Volatile Organic Compounds) while processed in Ultimaker 3D printers (not covered by warranty). These can cause headaches, fatigue, dizziness, confusion, drowsiness, malaise, difficulty in concentration and a feeling of intoxication. The usage of a fume hood is recommended.

2.4.4. ELECTROMAGNETIC RADIATION ISSUES

The distance from sockets should be proper so as to avoid unintentional touch. Furthermore, the cable of each socket strip should cross the laboratory -from the power socket to the bench- through a safe path. This ensures that children and teachers will not stumble on them. All wires should be new and indestructible; in case the cable is torn or cut, it should be replaced immediately.

The students and teachers should not be very close to antennas of WiFi access points.

Ultimaker 3 3D printer has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules (https://ultimaker.com/). These limits are designed to provide reasonable protection against harmful interference when the equipment operates in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and -if not installed and used in accordance to the instruction manual- it may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference on his own expense. The EMC test report of the Ultimaker 3 or Ultimaker 3 Extended is available upon request. The Ultimaker 3 has been tested according to the IEC 60950-1, which falls under the low voltage directive. The Ultimaker 3 must be used in conjunction with the Meanwell power supply GST220AX and delivered power cord. In combination, they guarantee safe use in relation to short-circuit, overload, over-voltage and overtemperature. Always unplug the printer before doing maintenance or modifications (https://ultimaker.com/).

The Ultimaker 2 operates on 24 volts (Extra-low-voltage) and is therefore outside the scope of the low-voltage directive. The power supply meets all CE mark regulations and is protected against short-circuit, overload, overvoltage and over-temperature. For more information concerning electrical safety aspects we refer you to the Mean Well EC-Conformity Declaration for the GS220AX power adapters. Only use the Ultimaker 2 with power supplies and cables supplied by Ultimaker B.V. (https://ultimaker.com/)

2.5. Maintenance

At the end of each class:

- Always unplug the raspberry Pi
- Always unplug all DIY electronics material
- Always unplug the 3D printer
- Put into a box the semi-developed projects
- Put into a box all materials and equipment that were not used
- Turn off all main power sources within the laboratory
- Open at least a window or door to let fresh air properly flow within the laboratory, especially after any 3D printing project
- Visual inspection of possible wire tears or short circuits that might cause injuries
- Visual inspection of any damage of moving mechanical parts or furniture

3 Teacher training sessions

The teachers that have been selected to participate in the pilot activities will be trained in M9 (1st phase) and M17 (2nd phase), according to the eCraft2Learn project time plan. Indeed, the first round of teacher training in Athens and Joensuu (M9) will be followed by a second round (in Athens and Joensuu, M17) and will take place after the first pilot study with students, aiming to address possible issues that emerge during the pilot study implementation (such as additional support for teacher and familiarization with new resources). Workshops will take place in an iterative way involving 15 teachers in Greece and 15 teachers in Finland.

The teacher training sessions of each phase intend to provide all the necessary guidance on the anatomy and the integration of the learning ecosystem. The training will also highlight methods to allow the ecosystem exploration for the pilot activities with students (the later activities will take place from M10 to M13 and from M18 to M21). Valuable input on the design and implementation of the teacher training sessions is provided in WP2, WP3 and WP4. The teachers as well as the students will participate in validation activities during the period of the pilots. Evaluation of the training courses will be held through semi-structured interviews with trainees to provide feedback on the course and on the achievement of capacity building, as work of the WP5.

3.1. WORKING WITH A DIVERSE GROUP OF TEACHERS

In Greek pilots, people that applied and were finally selected for participation in the pilots of the eCraft2Learn project as teachers, are of diverse characteristics. This is an interesting (but expected) outcome of the interviewing process and CVs' assessment, needed for the selection of teachers amongst the candidates. This fact reflects the rule that people of different ages, skills, education etc. can have enough capabilities to participate in the teaching process. These persons' dreams, expectations, priorities are not the same and therefore their teaching profile does not have to be the same either. This diversity is not a weakness but a real strength for the project’s expectations. In general, it is important to know the profiles of the teachers that are going to take part in the teacher training workshop. Having a clear picture of the profiles of the participants, helps in preparing or updating the training plan in line with their needs. The overall process is willing to make use of the benefits of good pedagogical principles like inquiring teaching, peer teaching and constructivism.

In Finnish pilots, experienced teachers (as assured by the Finnish laws) are participating. They were invited and they accepted the invitation. For the informal settings, experienced educators were invited, the ones that already run the science clubs after school hours, so these educators already have that experience (though they are not necessarily certified teachers)

3.2. FOSTERING THE ECRAFT2LEARN CONSTRUCTIONIST LEARNING ECOSYSTEM

It is intended for teachers to experience first-hand the kinds of activities that will be developed within the eCraft2Learn ecosystem. The teacher training will follow the axiom *“teachers teach as they are taught and not as they are told to teach”*. The eCraft2Learn workshops approach teachers as learners first; then it is about modelling the process of learning for students and showing teachers what intrinsic motivation, curiosity and creativity is expected (for more details see WP3/ D3.1). The work described here is trying to explore most of the pedagogical practices described in WP3 that are referring to teachers’ education.

3.3. ORGANISING THE TEACHER TRAINING SESSIONS

During the teacher training sessions, it will be recommended that teachers form groups of two (2) sharing the same workstation unit. Priority should be given so that each team consists of persons of different skills and working background.

Participating educators should understand the anatomy and functionality of the eCraft2Learn ecosystem and try to implement the most critical parts of the artefact creation projects intended for students (see section 4 of this document).

The trainers of the teachers will introduce issues like “Arduino Uno”, ”Raspberry”, Snap4Arduino and the teacher will seek the rest of the information and implement indicative examples. A reasonable set of resources/information will be available at each of the pilot sites, in order to accelerate the process. The main idea is to encourage teachers to explore the tools of the eCraft2Learn ecosystem and the underpinning pedagogical approach, through small-scale projects, ensuring that there will be time for free experimentation and real practical engagement. It is equally important to receive feedback by the participant teachers; their feedback will provide valuable information for the development both from a technical and a pedagogical perspective. It is foreseen that at the end of each session, teachers will be given the chance to talk about their experience. At the end of the training workshop sufficient time will be allocated to gather formally (see section 5/evaluation plan) feedback by the participant teachers. This include their overall experience, challenges that they faced, applicability of the learning intervention in their teaching practices; it is equally important to encourage them to elaborate on the use cases developed in D3.2 and to understand how the tools suggested and what they learnt, can be used in their teaching so as to improve it.

Table 1 presents an indicative plan for teacher training. It includes 5 sessions of approximately 4 hours each. The training workshop starts with an introductory section that involves ice-breaking activities. It is important to offer teachers opportunities to get to know each other, given that they are supposed to work collaboratively towards the creation of artefacts. Then through small projects they will be given opportunities to become familiar with the way the selected tools and technology operates. The aim is to support them in understanding the basic through projects that have a "low floor"(an easy way to get started) and "a high ceiling" (lots of possibilities for taking things even further). These types of projects are ideal when the group is heterogeneous involving many novices to the subject area. In the last training session, the participant teachers are encouraged to work on a free and open project that exploits the tools and resources embedded in the eCraft2Learn ecosystem; the project idea will be decided by the teachers based on their interests and the eCraft2Learn team will support them discreetly. The training workshop concludes with a feedback session; getting the teachers’ feedback, as already mentioned, is a very critical aspect of the training operation as it can influence future updates and improvements. An indicative plan of activities is given in Table 1.

Week #	Scenario #	Software & Hardware	Description
1A [1hour]	Knowing each other and forming the teams Breaking-the-ice activities	Brief overview of Lab's environment Teachers to become familiar with the laboratory equipment	Teachers (and their trainers) are starting to know each other, they introduce themselves, questions like *why here?*and*what is all about?*are answered. Teams of 2 teachers each are formed.
1B [1hour]	Teacher as coach, maker movement in education	-	The transformation of teacher's role to that of a coach is introduced to trigger discussions, first in groups and then in plenary, that will connect the lab activities to theories behind the maker movement with a focus on constructivism & constructionism. Teachers work out the 5-stages eCraft2Learn learning methodology through a following (1C) learning scenario.
1C [2 hours]	Indicative Activities highlighting the Arduino Uno programming capabilities using both textual and visual programming tools	Arduino Uno Arduino IDE Ardublock or similar. Basic sensor and actuator components.	The lighthouse example artefact (see section 4) will be the basis of these activities.
2 [4 hours]	Activities highlighting the RPi3 programming capabilities using both textual and visual programming tools	Connecting sensor and actuator components on RPi3 The composite RPi3/Arduino Uno system and the Snap4Arduino visual programming tool	Sensor triggered voice message invocation case, blinking LEDs and turning motors.
3 [4 hours]	Activities focusing on tablet devices visual programming and interconnection with RPi3 or Arduinos.	Remote connection to a Raspberry Pi 3 unit Tablets, Arduinos, Raspberries.	Remote user triggered sound invocation, blinking LEDs and turning motors.
4 [4 hours]	3D modelling and 3D printing skills - print simple objects	3D printer	The teachers investigate how to design and print simple objects using the 3D printer through the raspberry pi unit.

Week #	Scenario #	Software & Hardware	Description
5 [4 hours]	Free (but plausible) project implementation Collection of feedback	All	No specific scenario is given here. Teachers make their own (plausible) scenario or try to find solutions to issues left incomplete during the previous sessions. At the end of this session the teachers will provide us with their feedback; they will be encouraged to comment upon the use cases developed in D2.1 as well as to speak about their experience and the extent to which the knowledge gained can improve their teaching practices.

Table 1. The indicative plan of activities for teacher training

An indicative more detailed work plan in the form of a worksheet for teacher training session 1 follows:

1. Introductions/Ice-breaking activities (30 min)
2. Teams forming (10 min)
3. Training activity for introduction of the eCraft2Learn 5-stages pedagogical methodology (60 min)

Aim: To trigger discussions between trainer and teachers/trainees in order to familiarize the trainees with the 5-stages methodology that will be deployed in eCraft2learn pilots

Method: Teachers work in groups of 3-4 to elaborate the following topic/question (15 min):

Selecting the proper learning and teaching methodology is crucial for successful making activities in school classes. It is not enough to introduce robotics in class, technology alone cannot affect minds; robotics must be integrated in a well-designed learning methodology.

Study the eCraft2learn 5-stages methodology in the following pictures:

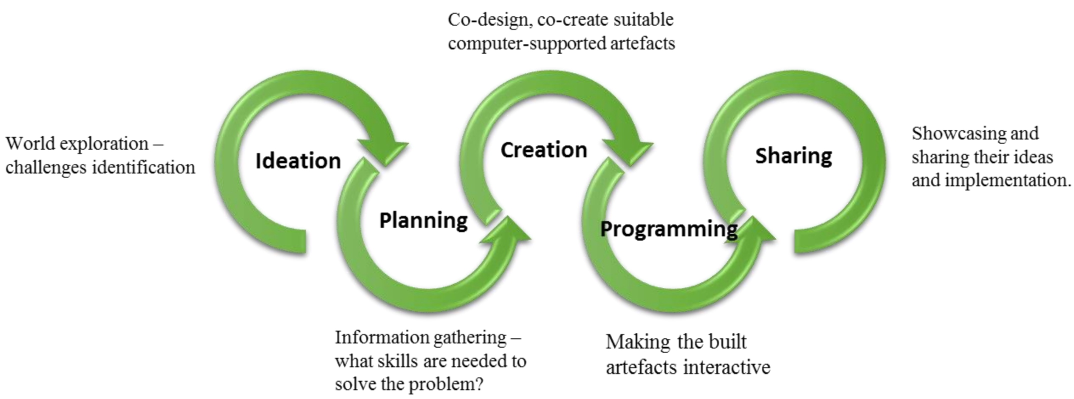

Figure 3. The eCraft2learn 5-stages pedagogy

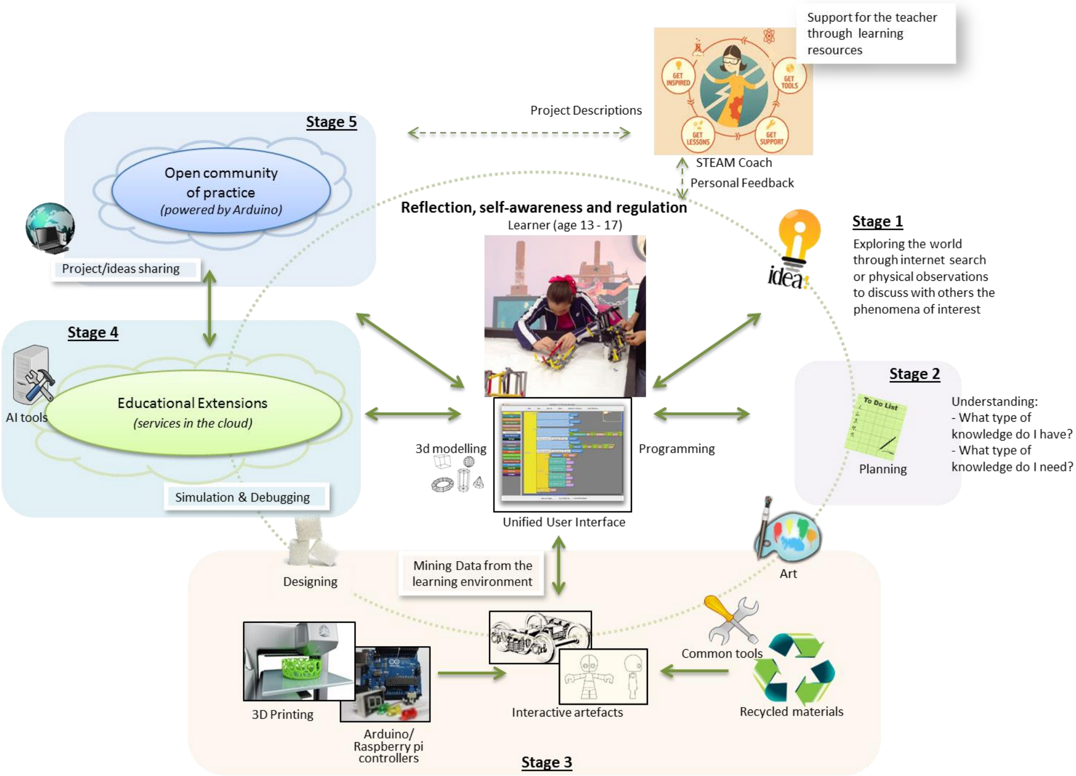

Figure 4. The eCraft2learn 5-stages pedagogy in details

Discuss within your group the following questions:

- Do you find all five suggested stages necessary?
- Which stages are more important?
- Any stages that might be omitted?
- Any additional stage you would wish to include?
- Would you suggest a different sequence of stages?
- Do you think this methodology is applicable in school reality?

A plenary discussion follows where one representative from each group reports shortly the answers of the group. This can be an excellent opportunity for preliminary feedback collection. More precisely, the results of this discussion can be documented by the eCraft2Learn implementation team as they may inform/update the development of the eCraft2Learn ecosystem. The discussion concludes with the recommendation of additional relevant resources for further study.

4. Activity: "Getting familiar with Arduino programming environment and visual block programming tools" [Based on the Lighthouse artefact]
    1. Connect your Arduino Uno unit to the Raspberry Pi board and verify the connection settings through the Arduino IDE software menu Tools -> Port. Tip: The USB cable is used for both power supply and communication issues.

2. Try to make the LED on pin13 of the Arduino Uno board to blink (to alternate from on to off state) every second. Tip: From within the Arduino IDE software menu go to File -> Examples -> Basics -> Blink and upload the relevant code.
3. Make the LED on pin13 to blink at different rates by modifying the on and off period duration.
4. Make the pin8 of the Arduino Uno board to blink instead of the pin13. Tip: Use a led in series with a 1kΩ resistor[1].
5. Read and inspect analogue values from the pinA0 of the Arduino Uno board using the File -> Examples -> Basics ->AnalogReadSerial code and the Tools -> Serial Monitor option. Tips: Connect the A0 pin to the ground / 5 Volt / 3.3 Volt pin (each time) using a wire – what do you see? Connect the A0 pin to the center pin of a potentiometer using a wire (the other 2 pins of the potentiometer should be connected to ground and 5 Volt respectively) – what do you see?
6. From the Arduino IDE, under Tools menu, invoke the Ardublock tool and try to implement tasks 2 through 5 using the visual block programming capabilities of this tool.
7. Connect (instead of a potentiometer) a photoresistor / 1kΩ resistor to the pin A0 of the Arduino and write down the corresponding values, for day and darkness conditions (use curtains or your hand to change the light level).
8. Make the LED connected to pin 8 to be on, only at darkness.

4 CARRYING OUT THE PILOTS WITH STUDENTS

The eCraft2Learn project aims at introducing digital fabrication in formal and informal education settings and to support a paradigm shift in educational robotics (and embedded systems) technology from “black box” and silo products to the “white box” paradigm where learners become “makers” of transparent computer-supported artefacts. Based on this concept, the pilot activities with students will take place from M10 to M13 and from M18 to M21. As discussed earlier, these pilot activities for both formal and informal education settings, will take place in Athens and Joensuu, in Greece and Finland, respectively.

4.1. PEDAGOGY MATTERS

The main goal of the eCraft2Learn project is to contribute to the personal development of the young learners (aged 13 to 17) as creative makers, critical thinkers and problem-solvers, and to promote science citizenship. This can be done by engaging the young learners in the making activities within a constructionist (Papert, 1980), personalized and user-driven approach. Work in the envisioned ecosystem will be interdisciplinary combining science, technology, engineering, arts, and math (STEAM) subjects.

[1]kΩ is the symbol for the kilo ohm

Project and craft based learning methodology

The proposed methodology draws upon project-based learning (PBL), a teaching and learning methodology that engages learners in sustained, cooperative investigation and includes authentic content, authentic assessment, teacher facilitation, explicit educational goals, collaborative learning, and reflection (Carbonaro et al, 2004).

Project based learning is a model for classroom activities, that shifts away from the classroom practices of short, isolated, teacher-centred lessons. PBL helps make learning meaningful and useful to students by establishing connections to life outside the classroom, addressing real world problems and developing real world skills. PBL supports learners to develop a variety of skills including the ability to work well with others, make thoughtful decisions, take initiative, solve problems, develop self-directed learning skills and motivation for learning. Thus, established principles of learning, such as motivation, relevance, practice, active learning, and contextual learning operate significantly in a PBL environment and to a much lesser extent in conventional curricula.

The eCraft2Learn project draws upon the project-based learning (PBL) methodology and refinements towards crafting artefacts. The projects that the students are involved into focus on computer supported artefact creation guiding them through five stages: ideation, planning, creation, programming and sharing.

In the classroom, craft and project-based methodology provides significant opportunities for teachers to communicate and establish relationships with their students. Teachers are required to be ready to shift their role based on modern didactic practices and to become facilitators, scaffolders and co-learners.

Implementing the eCraft2Learn learning paradigm and the scaffolding mechanisms

The projects that will be addressed to the students should integrate aspects of real, relevant and meaningful learning. The projects should provide links to different subject/cognitive areas and the real world. The projects should address problems that have personal relevance to the learners. To this end, authentic contexts and interdisciplinary scenarios may create opportunities for engaging learning experiences (Alimisis, 2013).

The learners can “engineer” or alter the proposed scenario; they can extend the scenario or design their own scenarios personalizing the robotic learning experiences. This will allow learners to move towards a more self-directed approach and work on projects that are in line with their interests and needs.

“What if” experiments are encouraged, for instance, through the changing of parameters. In this way, learners will be challenged to explore alternative solutions and explore in depth the underlying scientific concepts.

Active reflection upon the task: during the execution of the task the learner can stop the execution, ask for feedback and take time for some reflection on his/her previous action.

Guided skill development: the learners can seek more support while working on complex tasks. Supporting resources will be also available in the form of worksheets and videos (for example video and programming code to be followed) to guide the learners' engagement in robotic constructions and programming without revealing solutions. The solutions are not given; the path to the solution is described in a constructionist way.

Going beyond trial and error strategies

Usually students begin their problem-solving efforts using **trial-and-error** strategies that result in weak solutions and poor learning results. However, these trial and error practices might be a first necessary step to engage students in useful explorations within their projects and offer opportunities for teachers to encourage students over time to progress beyond trial-and-error strategies and try out more rational approaches to problem-solving that will be closer to the scientific mindset.

Embodiment

Very often students intuitively use their own bodies to reason about how to program a specific behaviour for their robotic device. While students are trying a modelling strategy to reason about the problem, they should be encouraged to use either the robotic materials or their own bodies to simulate the desired movement of the robot. For instance, a student's hand might be standing in for the robot and students are moving their hands in the manner that the robot should be programmed to move. This embodied activity might serve the learning purpose better than physically moving the robotic device resulting in **embodied cognition** (Dijkstra et al., 2007).

4.2. TEACHERS' AND STUDENTS' ROLE

The teachers are there to encourage students to proceed with their artefacts and assist them in finding all the necessary information and resources to complete their work. The teachers' presence should be very discreet; they are there just for the young students to feel confident and should provide as little help as possible and never give out-of-the-box solutions but rather show the path to follow. The eCraft2Learn project approaches the teacher as the facilitator of the learning process, the one that scaffolds the students' learning, gets involved in co-creation and co-design, assists them in picking apart ideas, forming their own thoughts and owning material through self-exploration and dialogue. The students in the eCraft2Learn ecosystem will have the chance to see their teachers as inspiration partners as well as models for their own learning. The role of the teacher will be that of a coach and not that of the person who has all the answers and makes the job done when nobody else can do so. Both teachers and students will follow a constructionist style of learning and making.

Overall, the teachers:

- set the pace, ensuring that the students freely explore ways to approach the project or implement their ideas
- facilitate the learning process and ensure that all the teams are progressing smoothly

- provide explanations when needed

As far as the students are concerned, these are first encouraged to reflect upon the problem that is addressed through the project. Discussion can take place in a group; then the group -supported by their teacher- sets up an action plan to solve the problem. The students work in groups to implement the plan, taking into account the teacher's feedback. The students may redefine the action plan after the experience gained during a preliminary work. They are invited to creatively synthesize the parts of the solution and reach conclusions regarding the problem under investigation. The final products and solutions of the groups are presented in the class, discussed and evaluated. Finally, the students are invited to reflect upon their work, express their views and record their experiences in a diary. Students should be allowed to spend some time playing with the robotics devices, to walk around and collaborate with classmates.

4.3. Getting started: Implementation of the pilots

According to the project's design anyone of the four eCraft2Learn ecosystem pilot sites (2 in Finland and 2 in Greece) will train about 30 young students, aging from 13 to 17 years old. The topics to be covered and the artefacts to be created are selected in a way that encourages girls and not only boys to get involved, and, in general, students of different characteristics and skills. More specifically, the ecosystem tends to promote the link between science, technology, engineering and math with arts, in order to encourage the inclusive participation of students with all levels of technical skills and also to reduce the technology-triggered gender divide, hence attracting more girls to the technical arena in all areas. The overall approach is intended to lead to the demystification of new technologies and free the creative capacities of the learners.

The sections below describe key steps that should be implemented during the pilots both in formal and non-formal educational settings. Given the educational setting (formal and non-formal), the process may differ or simplified. Possible variations are highlighted in the sections below. However, the activities that are going to be implemented are the same in both settings. In the formal education setting (public schools in Greece and Finland) the eCraft2Learn workshops will be integrated in the school program; in the non-formal educational setting, the workshop will be scheduled to take place after school hours or during weekends.

4.3.1. Forming the teams

One of the most important things is to "break-the-ice" between humans participating in the learning process. For this reason, the ice-breaking activities are very important and should be done at the beginning of the pilots. At this stage, it is important to activate the necessary mechanisms for the "group-development process", to actually compose the teams and to set a basis upon which good relationships among the team members can be established. The 1st session starts with icebreaking activities, the setting of the ground rules and the elaboration of the process which the students will go through. All these steps are important before the engagement in the eCraft2learn activities. By ice-breaking activities we mean the introduction to activities that are used at the beginning of a workshop to help participants feel like a team and be comfortable with their educators.

Two well-known methods to implement icebreaking activities are:

- Present yourself: Ask students to introduce themselves. Each student refers to his/her hobbies and interests, his/her previous project experience and his/her expectations from this workshop.
- Concentric Circles: This is an ice-breaker that gives children the opportunity to have short one-to-one conversations with each other. It also offers educators the freedom to adjust the questions to be asked, according to the needs of the day or the characteristics of the students' group

At the next, last part, of the ice-breaking activities, students will be asked (e.g., through oral group interviewing process and focus group discussions) to answer what their skills/preferences are. Indicative areas for such a classification should be:

- Students who prefer programming most
- Students who prefer creating/making things with their hands
- Students who prefer organising/presenting work being done

At a second stage, one person from each one of the three groups (formed using the criteria of the previous stage) will be chosen so as to form about 10 teams, each one having members of diverse skills and preferences. Specific care should be put so as not to have teams consisted all of boys and others all of girls.

If the abovementioned method does not give a satisfying solution for all teams to be formed, the rest of the student teams will be filled randomly.

Considerations for formal and Informal educational settings

This process may be more straightforward in the formal educational setting where students probably know already well one another; the teachers may also already know the students (unless they come from different classes), their skills and interests. For this reason, the ice-breaking can be omitted and the team formation process can be simplified. In any case, it is important to cultivate a nice and warm working atmosphere.

4.3.2. Setting the rules (didactic contract)

It is also important to create a set of rules that will reflect the accepted behaviour in the group and in the eCraft2Learn lab, for both teachers and students (didactic contact). The best way to create a set of rules in a classroom is to decide them as a group. Make sure that everyone contributes and makes suggestions. You can then document the rules that you all agreed on. The documentation will help possible future reference to the rules.

Rules may focus on the following topics: project tasks and outputs, time assigned to each project, group/classroom behaviour, use of the equipment, storage/uploading/downloading of files, submission of designs to the 3D printer, safety rules in relation to wiring the various parts or 3D printing and more. It is important to ensure that the appropriate rules have been set for establishing a positive atmosphere for peer learning, smooth project deployment and ideas sharing.

As part of this stage, teachers should also explain time assigned to each project and students' responsibilities. Students should keep a record of the entire process (ideas, paper-based models, 3D models files, codes, etc.). Furthermore, at the end of the workshop, students will be encouraged to talk about their experience, so it is important for them to know this in advance.

Lab safety rules require special attention and the teachers should play a key role in setting and communicating them. These should not be decided as a group; the students should be informed about the safety laboratory rules, the accepted activities and the emergency procedures during the 1st training session. Effort should be made by the teachers to address situations that may pose a hazard in the lab or a threat in the students' safety as well as to answer any eventual questions addressed by them. The safety guidelines can be documented also in a poster including possible hazards, good practices (Do's) and forbidden actions (Don'ts).

4.3.3. Describe the process

Before introducing the project in the class, the teachers should have exposed themselves to it. This will happen as described above (see section 3.3) during the preparatory teacher training workshop. This is important in order to better understand the challenges that the students may encounter and plan accordingly. It is equally important to explain to the students -before their real practical engagement in the eCraft2Learn projects- what the outcome of a project might be: a product, a presentation, a service etc. This gives a sense of purpose from day one. The provision of more project-specific information and practical guidelines can then follow.

The young students will attend approximately 12 sessions of 4 hours each, in order to become familiar with the eCraft2Learn ecosystem and create their own projects. The earlier stages of the training period should be organised in a way that lets students achieve fast and encouraging results allowing for deeper engagement and more complicated approaches during later stages. Students of different skills and preferences will cooperate within their teams, in order to proceed with their work. Apparently, peer learning techniques will be applied as well. More specifically, one student will act as the coach for another student, mainly in the same team, on issues for which the first is an "expert" and the second is a novice.   [Ideation -> Creation ->Programming -> Sharing/Presenting].

4.4. Implementing the interdisciplinary STEAM projects

The artefacts to be created will involve Arduino units, raspberry pi units, DIY electronics, simple constructions using recyclable materials and simple 3D printed parts. The overall process will not be limited to conventional robotic constructions or typical STEM projects but will pace towards STEAM work and Physical Computing, thus addressing to a wider area of students.

As it has already been mentioned, the teachers act as facilitators encouraging participants to deal with failure and learn from it. They invite students to point out what they found compelling and interesting in their work. The interdisciplinary STEAM projects are seen as extended learning opportunities, and not just for the students.

4.4.1. INDICATIVE PLANNING OF ACTIVITIES

As mentioned above, the activities and artefacts to be done will be organised in a 12 sessions period. The students' dynamic is expected to vary in terms of skills and preferences. The topics to be covered will be characterised by great diversity as well, so it is rare to happen that the same student has the dominant role in the team, throughout the whole time that the teaching period lasts.

The overall planning will not restrict the students' teams to implement exactly the same task/artefact. The suggested scenarios are indicative and offered both as guidance and inspiration for the students to create similar or better artefacts on their own. In all cases, students are working using the raspberry pi based workstation units. The suggested scenarios are better suited to the 1st phase of pilots (M10 – M13); refinements should be done for the 2nd phase after useful feedback has been collected. The overall idea is to encourage the students -through small-scale projects- to explore the main thematic areas and tools comprising the eCraft2Learn ecosystem. The same methodology used for the teacher training is also applied in the pilots with students. However, online training and personal study (that is expected by the teachers) is substituted with more sessions for practical experimentation in the case of the students. The areas to be covered are given in Table 2; as a result, the training plan is very similar to the one proposed for the teachers. However, this plan includes more sessions that span in 12 weeks. It is worth mentioning that after the completion of each core project the students will be encouraged to document their feedback using team diaries (for more information see section 5- general evaluation plan). It must be noted that access to the various tools, being necessary for artefact programing or creation, as well as to further educational resources is provided via the unified user interface (UUI) of the eCraft2Learn ecosystem.

Week #	Scenario #	Software & Hardware	Description
1	Knowing each other and forming the teams Ice-breaking-activities Setting the rules (didactic contract)	Brief overview of Lab's environment Students to become familiar with the laboratory equipment	Students (and teachers) are starting to know each other, they introduce themselves, questions like *why here?* And *what is it all about?* are answered mostly by the students themselves. Teams of 3-4 students each are formed, using techniques described in section 5
2	a) Blinking a led and reading an analogue value b) The Lighthouse project	a) Arduino Uno / Arduino IDE b) Ardublock or similar Potensiometers,	a) Students will try to make a led to blink at different rates and inspect analogue values to be captured using a simple potentiometer. The task of gluing together these two tasks will be left as an exercise. b) Students, using paper/plastic bottles,

Week #	Scenario #	Software & Hardware	Description
		Leds, Photoresistors	will construct a lighthouse miniature having its light blinking at a specific rate and only at night (i.e when external light is low) Feedback through the use of team diaries.
3	The shy rabbit project	Arduino Uno /Ardublock or similar Angle servo, Microphone with amplifier, Some wire cables	Students are sketching a rabbit on a paper, they put it on an angle servo and move it up or down depending on microphone readings (i.e. a loud sound makes the rabbit to go down). Feedback through the use of team diaries.
4	3D modeling and printing skills – print simple objects	3D printer	The students investigate how to design and print simple objects using the 3D printer through the raspberry pi unit. Feedback through the use of team diaries.
5	The Sunflower project	Arduino Uno / Ardublock / Snap4Arduino / RPi3 Angle servo	Students are 3D printing a flower; they put it on an angle servo. The flower will be able to move around its axis according to photoresistor array readings, in order to enjoy the sunshine. Feedback through the use of team diaries.
6	The scent-emitting flower	Arduino Uno / Ardublock / Snap4Arduino / RPi3 Small electric fan, Photoresistor,	Students are 3D printing a flower; they put it on the top of a plastic bottle. They put a motor and a fan inside the bottle and a few drops of perfume. The artefact is programmed so as to create a scent emitting air flow whenever the light conditions are low. A photoresistoris used to distinguish between day and night. Feedback through the use of team diaries.
7	Sensor triggered sound invocation	a) Arduino Uno equipped with distance sensor and speakers. b) RPi3, Photoresistor, resistor, speakers. c) Same as in case b) plus an Arduino Uno as a sensor board.	Voice/sound message invocation on an RPi unit, according to luminosity or distance sensor readings.(At least two of the previous-column variances will be explored) Feedback through the use of team diaries.
8	User triggered sound invocation - RPi3/WiFi implementation	RPi3, (it has WiFi on board), speakers,	Students are shaking a tablet (or pressing buttons), thus invoking a sound to be produced by a pair of speakers connected to a RPi3 unit. Communication is done via

Week #	Scenario #	Software & Hardware	Description
		Android tablet, Some wire cables	the WiFi interface. Feedback through the use of team diaries.
9	a) Driving a bug using a RPi3 unit and a tablet b) Driving a bug using a RPi3 unit and the VNC environment	RPi3, (it has WiFi on board), Servo motors with wheels and a motor driver circuit, Android tablet, some wire cables	a) Students are 3D printing a bug-like shell and a chassis for a small robot. After that, they equip it with servo motors and a RPi3 unit and drive it through the WiFi interface of their tablet. b) Same as in previous case but now students drive the robot through the WiFi interface of their workstation using a VNC connection to the remote raspberry (part of the artifact). Implementation may include Scratch or event Snap4Arduino and an Arduino unit. Feedback through the use of team diaries.
10	a) Driving a virtual bug using gestures/light b) Driving a real bug-robot using gestures/light	a) RPi3, Arduino, distance or light sensors b) Same as described above but now the focus is to control an actual bug-like robot	a) According to distance or light sensor readings a virtual bug-robot (in Snap! or Scratch) environment is driven. b) Same as described above, but now the bug-robot is real. Feedback through the use of team diaries.
11	Light Sensor Data Visualisation locally or via the web	RPi3 for visualisation and Arduino Uno as sensor board, Photoresistor, Snap4Arduino.	Arduino provides luminosity data (using a photoresistor) to the RPi3 unit that changes the Snap4Arduino (or Scratch) scene accordingly. It will be explored if the the above data per team can be posted on a web server for public view. Feedback through the use of team diaries.
12	Free (but plausible) project implementation and feedback collection	All	Not a specific scenario is given here. Students make their own (plausible) scenario. Feedback through questionnaires for the overall experience and focus group discussions

Table 2. Indicative Planning of Activities for the Pilots with Students

4.4.2. ADDITIONAL CONSIDERATIONS

Project implementation and failures

Failures are very likely to happen. Review and peer feedback may decrease the number of failures but they will still happen. It is important to use a failure (i.e. a failed print, a sensor that does not operate as planned etc.) to challenge the students' thinking on why their design failed or mis-functioned. Failures may disappoint students and make them reluctant because of the fear of another failure. It is of great significance to stress the fact that failure is "part of the game" and that it constitutes a didactic narrative.

Discussion matters

When the final project is ready, the teachers can raise a discussion among teams. This can help students reflect upon their work as well as provide the eCraft2Learn team with useful feedback based on their practical experiences. Indicative questions that can be raised:

- Is this the expected result?
- Are the team members happy with the final outcome?
- What did not go well?
- Through which stages did they go through?
- Do they have ideas for new projects?
- How can this experience be presented in public?

The discussion denotes the official closure of the project and the beginning of a new project. Team diaries may also be used for documenting relevant information.

Presenting/Sharing the project

The most important parts of the work being done (i.e., artefacts photos and/or videos, interesting construction moments, indicative code blocks, 3D models) and a brief description will be circulated among teams, shared/presented at a lab site level and uploaded on the eCraft2Learn cloud to be formed for further exploration and inspiration. Things can start early on the local sites by taking advantage of the ability that the RPi has to host web server engines, like Apache (https://httpd.apache.org/) and the flexibility that file sharing tools are providing, like the WinSCP file application (https://winscp.net/eng/docs/introduction) or the FileZilla (https://filezilla-project.org/). A separate RPi unit could be dedicated to these tasks. Last, after receiving feedback from the 1st round of pilots, augmented reality solutions and the ThingiVerse platform will be also considered, as they can offer ideal opportunities for 3D model and artefact sharing and contextual visualization.

5 GENERAL EVALUATION PLAN OF PROJECT ACTIVITIES AND LEARNING INTERVENTION

The primary aim of all evaluation findings must be the refinement of the eCraft2Learn ecosystem, leading to new and improved specifications that ensure the educational value of the suggested learning intervention.

The evaluation plan builds upon two axes:

1. The extent to which the teacher training workshop fulfilled its aim and properly prepared teachers in carrying out the eCraft2Learn learning intervention with their students.
2. The impact of the learning intervention on the students' learning and skills development.

The feedback that will be retrieved by teachers and students will inform the 2^{nd} pilot phase and will possibly show remedial actions that should be undertaken both from a technical and pedagogical perspective by the eCraft2Learn implementation team. To this end, questionnaires (web or paper-based) can be used to collect data from the teachers that participate in the training workshops and the pilots; in-depth interviews or focus groups can be used to explore particular issues in more detail.

It is equally important to receive feedback from the students in order to explore the extent to which they benefitted by the eCraft2Learn learning intervention towards the development of the targeted 21st century skills. The eCraft2Learn pilot evaluation plan for collecting feedback from the students towards this direction, could include a comparison with the prior set of answers of the pilot learners' group (through the use of pre-and post-tests that aim in alleviating the students' skills, interests and attitudes towards STEAM related disciplines)

In addition, it is useful to gain an insight into the students' experiences and offer them opportunities to share their experiences with the eCraft2Learn implementation team through the use of questionnaires. The questionnaires could take the form of a diary that to be updated on a regular basis (it can include questions that can be easily answered by the students like: What did they like mostly? What did they like the least? Do they feel that they learned something new? What went wrong?). Questionnaires that offer students the opportunity to document their feedback supported (if necessary) by focus group interviews, which allow the researcher to alleviate issues inherent in the questionnaires, can offer an insight into students' perceptions and experiences.

Observations during the teacher training and pilots with students may also reveal useful information about the physical setting, the make-up of the individuals being observed and the interactions that are taking place. In addition to that, observation will enable the eCraft2Learn team gather data on the programme setting (i.e. resources and their organization, workshop design, learning practices etc.)

Personal notes, log files, field notes and other useful personal documents produced by the participant teachers and students (including their projects) during the pilot phases can be also useful for the evaluation of the learning intervention and will help the eCraft2Learn consortium to introduce the appropriate mechanisms for improvement. The data gathered through personal documents, can be used to support claims or to enhance existing assumptions. They can also point out new research areas or subtopics that should be further studied. However, 'interpretation' is a crucial issue when using personal documents. The 'composer's motivation and thinking' is also worth of bringing into focus. For this reason, researchers often use personal documents and then carry out interviews to alleviate issues inherent in personal documents, to test the validity of their claims and to gain a new insight on the data gathered.

It is also worth referring to an important asset of the eCraft2Learn project evaluation procedure which is the development of a learning analytics system that collects data from technical parts of the framework, such as the 3D printers and the programming environment but also from the learners' and teachers' interactions with the learning environment. Raw data is processed with appropriate data mining models, such as decision trees and other more advanced probabilistic artificial intelligence methods. The aim is to classify, detect, and foresee factors that potentially affect the learning processes and outcomes, and inform and guide learners and teachers working with the projects. To avoid abovementioned problems with "black-box" thinking on learning analytics tools, we will apply previous research results (Jormanainen & Sutinen, 2014) where we have shown that empowering teachers working in the robotics classes to direct the data mining process, produces valuable insight into the progress of the learning activity even on relatively small datasets. This approach opens up data mining and intelligent tutoring processes, usually in a black box, to learners and teachers, and engages them to use their contextual knowledge and pedagogical expertise "in-situ" to build training sets for machine learning algorithms from raw data with a simple graphical user interface. Based on these data sets, predictable learning analytics models are then built in the system real-time, hence trying to reflect the current situation in the learning process. Iterative development allows refinement of the models and they potentially become more accurate and expressive when new data accumulates to the database, and teachers and learners are able to create more comprehensive training sets by classifying new data samples.

The data should be collected in a form that allows effective comparison with data/information being collected in the other pilot sites. It is equally important to ensure that data are in a similar form and structure to allow ready analysis/synthesis. Data collection starts early on in the pilot implementation period and will be on-going, ensuring that the findings are integrated incrementally into project outcomes.

6 CONCLUSION

This deliverable highlighted the first implementation of activities required to run pilots, including space structuring, equipment establishment and integration of the eCraft2Learn learning ecosystem in the selected 4 pilot sites, in Greece and Finland. The main goal for this ecosystem is to build a "culture of learning by making", which will encourage students of different skills and characteristics to do a great work of lasting value. The work and guidelines provided by the deliverable WP5.1 are reflecting the first implementation of the eCraft2Learn ecosystem and so, useful feedback and revisions will follow. Indeed, the data collected from this WP will serve as feedback for the further improvement of the implemented craft and project-based pedagogies and technical core.

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