eCraft2Learn

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

Deliverable D5.5

Small scale case pilot report and good practice videos

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EXECUTIVE SUMMARY

This report aims at describing the small-scale pilots with learners that were carried out in Greece and Finland in formal and informal educational settings. The small-scale pilots were conducted in two rounds including activities that aim at reinforcing learning by making in science, technology, engineering, arts and math (STEAM) education. Prior to deploying the pilots in formal and informal learning settings, the teachers were invited to participate in capacity building workshops that focused on using the eCraft2Learn tools and the corresponding pedagogical model. In the context of the pilots, the trained teachers enabled 13-17 years-old students to work with digital fabrication and making technologies for creating a number of computer-supported artefacts. The computer-supported artefacts that were created are described in this report. These projects undertaken for creating the artefacts are interdisciplinary in nature bringing together different disciplines from the field of Science, Technology, Engineering, Arts and Math (STEAM).

In an appropriate pedagogical model that supports different steps that are highly interlinked (ideation, planning, creation, programming and sharing), the teachers and students were invited to work together and explore the fun and the challenges of the *making* process using the eCraft2Learn learning ecosystem tools, technologies and resources. In this line, a number of good practices were identified related to the facilitation of the learning process, the support of the ideation, the boosting of the 'can-do' attitude, the embracement of failure and the encouragement towards sharing projects, experiences and ideas. Most of these practices are reflected in video-recorded episodes accessible through this report.

1 INTRODUCTION

This report describes the small-scale pilots with learners, that were carried out in Greece and in Finland during the project implementation period. The small-scale pilots were conducted in two rounds in formal and informal settings including activities that aimed at reinforcing learning by making in Science, Technology, Engineering, Arts and Math (STEAM) education, fostering interpersonal skills, assisting the development of 21st century skills that promote inclusion and employability for youth in the EU. Prior to deploying the pilots in formal and informal learning settings, the teachers were invited to participate in capacity building workshops that focused on using the eCraft2Learn learning ecosystem including technical tools and pedagogical model. In the context of the pilots, the trained teachers enabled 13-17 years-old students to work with digital fabrication and making technologies for creating several computer-supported artefacts. Embedded in an appropriate pedagogical model that supports different steps and phases that are highly interlinked (ideation, planning, creation, programming and sharing), the teachers and students were invited to work together and explore the fun and challenges of the making process.

Section 0 and **section 3** focus on the formal and informal pilot sites in Greece and Finland. The process that was followed in each pilot site is described together with important information about the context, the challenges that were faced, the role of the teachers and the practices that took place.

Section 4 presents the eCraft2Learn projects that were implemented by the students in the formal and informal pilot sites in Greece and Finland. The context of each project is described, the time for the creation is mentioned, information about the realisation and the technical part is also documented. Most of the projects that were carried out are cross-thematic in nature and cover different STEAM related disciplines. Some projects were in line with formal school curricula, others were proposed by the teachers, others were the result of the extension or the personalization of a given project topic, others came directly by the students.

Section 5 provides access to the real classroom/lab episodes that were video-recorded during the pilots. These videos reflect some good practices that took place in Greece and Finland. It is worth noting that the good practices videos (see list with videos in section 5) recorded during the small-scale pilots in the eCraft2Learn labs are in a form that can be directly disseminated, thus inspiring more teachers to embrace the eCraft2Learn initiative and informing future workshops and project exploitation and sustainability (WP6). **Section 6** then presents the conclusions and remarks, summarising the good practices that were observed in the pilots.

Connections with other tasks and work packages within eCraft2Learn

Focusing on **project implementation**, it is worth mentioning, that the work described in this report informs and assists other project tasks and work packages within eCraft2Learn. More precisely, the experience gained during the small-scale pilots with learners guided the design of the Open Educational Resources (OERs) (WP3, D3.3). Teachers' comments (see D5.2) that were based on their pilot experiences to some extent also showed the way towards updating the manual for craft- and project-based learning STEAM training for teachers (WP3, D3.4). The vast array of difficulties, both technical, administrational and pedagogical that were encountered during the pilots have been also documented in D5.3 'Recommendations for ecosystem refinement and improvement' report. The experiences gained during the 1st round of the small-scale pilots with learners in Greece and Finland were also deployed in order to customize the teacher training program (WP5, D5.2). In addition, the conduction of the small-scale pilot studies with learners (that are described in this report) allowed the ongoing generation of feedback that was analysed and documented in D5.4 (WP5) significantly contributing on the impact measurement on participating teachers and students.

Pinpointing the benefits for the school community

This report aims at elevating the good practices that were observed in the formal and informal pilot sites in Greece and Finland by presenting them as they emerged through their authentic contexts. The good practices that were identified are described together with the context within which they were observed, alongside the challenges, the difficulties and the calls for re-considerations. By presenting the good practices through their realistic framework, we aspire to encourage **more teachers** (from formal and informal education settings, in-training or in-service) to embrace the eCraft2Learn initiative and situate themselves in the eCraft2Learn ecosystem.

The description of the small-scale pilots highlights the importance of embedding the eCraft2Learn initiative within the school program by providing information on how this occurred in Greece and Finland. The documented actions and the challenges faced will be useful to **school principals and advisors** with interest in integrating the eCraft2Learn learning initiative in the school program.

Recognising that the collaborative nature of the maker mindset comes from an embrace of sharing ideas and projects, exchanging information and good practices, different sharing practices that were applied in both the informal and formal settings are described. In a similar way, practices that encourage the generation of ideas, enable learners to smoothly shape their own explorations, embrace failures and setbacks so that to provide opportunities for richer learning experiences are also described. All these descriptions are not only **useful for teachers interested** in the eCraft2Learn initiative but also for **those active in the field of teacher training**. In other words, we see our work as contributing to teacher training in the STEAM education field offering access to stories and good practices from the authentic eCraft2Learn maker space environments. The work reported in this deliverable, combined with other outputs of the eCraft2Learn project, especially D3.2 use case scenarios, D3.3 open educational resources, D3.4 craft- and project-based learning STEAM training for teachers, and D5.1 pilot protocol, and D5.2 capacity building workshops, offers useful information available for **teachers and teacher trainers** who wish to introduce digital fabrication and the maker movement in formal and informal education.

The projects that were carried out in the pilots through the eCraft2Learn learning ecosystem (see section 4), offered learners unique opportunities to explore the eCtaft2Learn tools and technologies, to shape their own explorations, to challenge seeking, to fail and keep trying, to express their creativity, to share ideas with classmates but also with people of a wide range of ages and knowledge. The documentation of these projects (together with the underlying context) can potentially **empower more teachers in implementing making projects in their classrooms.** The projects (see section 4) can be described as having a “low floor” and “high ceiling” as they offer an easy entry for novices (low floor) while enabling more experienced learners to work on increasingly more complicated projects (high ceiling); noteworthy, they have also “wide walls” as they can support a wide range of different explorations (Resnick and Silverman, 2005). In this light, the 19 projects that are described in the sections 4.1-4.19 can be **extended in new situations and contexts** or **inspire new ideas for more advanced and innovative projects**.

This report can be seen as a starting point upon which key stakeholders, including school principals, teachers, teacher trainers, educators as well as the broader school communities, can build. The goal of this report is not to establish a prescribed set of activities but to encourage actions that help build **a stronger evidence base for what STEAM teaching and *making* experiences work best in different contexts and serve diverse learners**.

Key takeaways from the small-scale pilots in Greece and Finland

Reflecting upon the small-scale pilots in Greece and Finland, there are some helpful takeaways that are worth sharing with teachers interested in the eCraft2Learn initiative. The key takeaways include:

- **The call for stepping out of your comfort zone.** The teachers in the eCraft2Learn ecosystem should be ready to step out of their comfort zone. Regardless their backgrounds and level of experience, they are invited to enter into teaching situations that they have never experienced before, to apply new practices, to explore new tools and technologies (3D printers, digital fabrication, Do IT Yourself (DIY) electronics, new programming tools, learning analytics tools and more) and experience once again what it is like to learn themselves.

- **Building a welcoming atmosphere**. In a group where the participants do not really know each other, ice breaking activities can get them comfortable with one another contributing significantly to the team bonding.

- **Transforming failures into learning opportunities.** The eCraft2Learn ecosystem invites failures and exploits them from a didactic perspective. The teachers should approach failures as opportunities for creating deeper and richer learning experiences within the eCraft2Learn ecosystem.

- **Supporting the generation of ideas**. It is important to encourage the students to work on projects that are meaningful to them. However, big ideas may not easily emerge. Even when the project scenarios are proposed by the teachers, it is important to offer students opportunities to extend the scenario of the project based on their personal interests and preferences. When the students work on something they really like, it is more likely to dedicate themselves in the making process, to engage in explorations and to come up with new and more advanced ideas.

- **Creating an atmosphere of curiosity and innovation**. In the eCraft2Learn ecosystem the teachers are not the sages on the stage and they are not supposed to have all the answers to the questions that may emerge. They rather help and encourage the students to explore and construct their own knowledge, to organise their thoughts and ideas, to work effectively in teams. They encourage team work, experimentation, hands-on activity, challenge seeking and the sharing of knowledge. As Seymour Papert (1993) advocated, 'the role of the teacher is to create conditions for invention rather than to provide ready-made knowledge'.

- **Sharing matters in the eCraft2Learn ecosystem.** It is important to provide students with opportunities to share their ideas, accomplishments, experiences and struggles with each other. It is important to show them that they can build upon the experiences and results of others and others can learn from their own experiences and outcomes. Sharing can happen in the class, in teams, in online platforms, in the Unified User Interface (UUI), in festivals, school events and more.

- **The importance of adaptation and role shifting.** The making process is not linear. It involves several stages that are interlinked and frequently take place in parallel. As a result, the teachers are moved to take several roles (the roles of the mentor, trainer, facilitator of the learning process, self-esteem booster, co-maker, co-learner, evaluator and more) and adapt their support and guidance based on the needs along the way.

- **Building partnerships.** The eCraft2Learn ecosystem calls for synergies and partnerships among teachers and educators of different disciplines (Science, Technology, Engineering, Arts, Math). In this way, interdisciplinary projects and innovative ideas can be better supported. In addition, within a partnership of teachers, it is more likely to deal with organizational and administrational issues emerging often in the formal school settings.

In the following chapters, the use of the word "teachers" refers to the teachers (formal teachers, informal teachers, educators) that had participated in the capacity building workshops (see D5.2) and worked with the learners in the context of the small-scale pilot studies in formal and informal pilot sites in Greece and Finland.

2 Description of Small- Scale Pilots in Greece

This section focuses on the formal and informal pilot sites in Greece. The process that was followed in each pilot site is described together with important information about the context, the challenges that were faced, the role of the teachers and the activities that took place. Section 2.1 focuses on the Greek formal pilot site, the 1st EPAL of Korydallos. Section 2.2 describes how the small-scale case pilot rounds were implemented in the Greek informal pilot site, the Technopolis City of Athens.

2.1. Formal Pilot site

The context

The formal eCraft2Learn lab was established in the 1st EPAL of Korydallos (Athens, Greece) that had agreed in serving as formal pilot site for the needs of the eCraft2Learn project (see also D5.1). The 1st EPAL of Korydallos is a secondary level school that enrols students from 15 to 17+ years old.

A very first challenge that was faced related to the integration of the eCraft2Learn workshops in the school program. The Greek school education system is centralised at the level of both planning and implementation. Curriculum contents, school timetable, textbooks, and teaching methods, are proposed and controlled by the Ministry of Education in public schools and to a high degree in private schools (Eurydice, 2005) as well. The implementation of the eCraft2Learn initiative after school hours, was a first option that was discussed yet rejected as this neither meant real integration in the school program nor constituted the desired way of introducing the eCraft2Learn initiative. Thereby, the eCraft2Learn implementation team together with the school team explored in detail the educational framework in order to find ways to bring the eCraft2Learn practice in the school program during formal school hours operation. The solution revolved around the 'Flexible Zone for Cross-thematic and Creative Activities', a flexible framework that the last years was launched by the Greek Ministry of Education to support the implementation of interdisciplinary and creative activities during school hours.

Integrating the eCraft2Learn initiative in the Greek school program

The eCraft2Learn workshops were integrated in the 'Flexible Zone for Cross-thematic and Creative Activities' of the school. The Greek Ministry of Education provides schools that operate under its auspices with the opportunity to activate this zone in order to run creative activities that emphasize on cross-thematic and team approach to knowledge. Within this framework, the "Flexible Zone of Cross-thematic and Creative Activities" aims at helping students develop their cognitive, social skills and critical thinking, while encouraging schools to open up to society. The flexible zone usually runs for 2 to 3 school hours per week as part of the ordinary school curriculum. This was considered as a good opportunity for the integration of the eCraft2Learn initiative in the formal school program which is usually predetermined centrally by the Ministry of Education in Greece. Taking advantage of this flexible framework, the school principal activated this zone providing an opportunity for the eCraft2Learn initiative in the form of weekly workshops of 2-3 school hours[1] each. The use of this flexible framework will be supported in the forthcoming school years, whereby all learners have the opportunity to engage into *making* in STEAM education. The dissemination of this practice and the experience that was gained, can inspire more schools to activate similar flexible frameworks for the implementation of interdisciplinary activities in STEAM education and beyond.

Organizational issues

The 1st pilot round was conducted with two classes, an overall of 30 students, 15 to 16 years old. Due to restrictions related to the school program during the Spring semester, the 2nd pilot round was carried out with a single class, the same 15 students that had joined the 1st pilot round. The teachers that supported the eCraft2Learn learning initiative were also the ones that had received training (see D5.2) by the eCraft2Learn implementation team. During the pilot rounds 2-3 school teachers were active in the eCraft2Learn lab, undertaking the role of the coaches.

The 1st pilot round lasted approximately 23 hours. The 2nd pilot round lasted approximately 15 hours. The duration of the 2nd pilot was shortened due to two main reasons a) the exam period was starting in June, making it difficult for the school to maintain the Flexible zone during that period and b) the students were more familiar with the eCraft2Learn tools and thus they entered directly into the *making* process working on their eCraft2Learn projects (see section 4).

The following table summarizes the key information regarding the two (2) pilot rounds in the Greek formal pilot site.

Table 1: Information about the 2 pilots rounds in the Greek formal pilot site

	Greek formal pilot site	
	1st pilot round	**2nd pilot round**
Total participants	30 students (2 classes, 15-16 years old)	15 students* (1 class, 15-16 years old)
No. of teachers	2-4 per class	2-3 per class
Team work approach	Work in groups of 3-4	Work in groups of 3-4
Time	2-3 school hours per week	2-3 school hours per week
Total duration	November 2017- February 2018 Approx. 23 hours	April 2018- early June 2018 Approx. 18 hours

** the same students that had participated in the 1st pilot round*

The selection of the 2 classes was made by the school based on organizational complexities related to the activation of the 'Flexible Zone' during that period for specific classes. Most of the teachers that were involved in the pilots were coming from STEM related disciplines and one from the field of Graphic Arts (see D5.2). The number of teachers that were present in each session varied depending on organizational school issues having as a minimum number, the 2 teachers and as the maximum 4.

[1] 45-minute segments 'units'

Implementing the eCraft2Learn methodology towards computer- supported artefact constructions

Following the pedagogical ideas underpinning the eCraft2Learn methodology, the **team work** was highly encouraged. The students early from the beginning were invited to form groups of 3-4. Given that the students knew one another, no time was allocated to ice breaking activities. As the sessions progressed, the students were noticed to support other groups as well, to exchange tips and to self-sufficiently allocate roles. In some groups, the students were equally involved in the project tasks but in most of the groups there was a distribution of roles and responsibilities. For example, some students were more involved into programming, others more into electrical circuit making while some others were taking care of the handcrafting tasks or 3D modelling. The reasons for this role allocation was related to time constraints and personal interests.

During the first (1st) session, focus was placed on familiarizing the students with the eCraft2Learn tools, technologies and resources. Some groups needed more time for familiarization than others, but the whole familiarization process was integrated into the *making* process and occurred through the practical engagement in projects for computer-supported artefact constructions. It is worth mentioning, that as the workshops progressed, the students became more confident in using the available tools and more eager in trying out different ideas. As the participating teachers pointed out, initially the students were a bit reticent but as soon as they became familiar with the available tools and technologies, they were seen to take initiatives for new projects and extended implementations.

The first projects that were implemented in the class were proposed by the teachers. The idea was to introduce the eCraft2Learn tools and technologies through easy to start with projects. Smoothly, some groups of students were noticed to take initiatives and to extend the project scenario implementing something new. For example, this was the case of the Small Village project (see section 4.2) which was actually an extension of the Lighthouse project (see section 4.1). As the sessions were progressing this practice was much more present.

The following table presents the projects that were carried out in the Greek formal pilot site, during the two (2) pilot rounds. As one can notice, some ideas for projects were proposed by the teachers, whereas others came directly by the students either as an extension of an existing project topic or as a completely new idea. There was also the case of projects, that emerged during teacher-student interaction and drew upon a project idea that had been earlier implemented. This was the case of the solar panel project (see section 4.7), that was actually transferring the functionality (from a technical perspective) of the Sunflower project (see section 4.4) into a different context. The solar panel project emerged while a teacher was discussing technical details related to the Sunflower project with a group of students; it was considered an excellent opportunity for learning to transfer and test the technical solution in a new context. The solar panel artefact that was created, was also seen as a didactic tool for introducing the concept of solar energy in more school classes. Another interesting case was the case of the 3D bridge project (see section 4.8); a class of 16-17 years old students were working on a project related to structures of historical and famous bridges in the context of the mechanical engineering elective course. This inspired the eCraft2Learn team to make a computer-supported artefact in this topic using the eCraft2Learn tools and technologies.

Table 2: The emergence of project ideas in the Greek formal pilot site

Projects	The project idea/topic was suggested by the teachers	The project idea/topic was extended by the students resulting to a new project or an advance one	The project was building upon another project that had been earlier implemented	The project idea came from the students
1st pilot round				
The Lighthouse project (see section 4.1)	x	x		
The Sunflower project (see section 4.4)	x	x		
Christmas artefacts (see section 4.5)				x
DIY automobiles (simple) (see section 4.6)	x	x		
The small village (see section 4.2)			x	x
The solar panel (see section 4.7)			x	
2nd pilot round				
The 3D bridge project (see section 4.8)			x	
DIY automobiles (advanced) (see section 4.6)			x	x

It is worth mentioning that as the sessions progressed, the students engaged more naturally in the creative production of different artefacts, based on their interests and at their own pace. For example, during the 2nd pilot round, some groups expressed an interest in working on advanced DIY automobiles (see section 4.6) while two groups joined forces and worked on the 3D bridge project (see section 4.8). Smoothly, the eCraft2Learn lab was transformed into a making space where various projects were being carried out in a collaborative manner, ideas were developing, testing and experimentation was taking place, lots of hands-on activity was on as well as failures that were engineering new circles of planning, designing and making.

Time, a critical factor

Nevertheless, this *making* atmosphere enforced by the open nature of the eCraft2Learn initiative, created tension with the predefined (by the Greek Ministry of Education) school agenda. Time was a critical factor and quite frequently the students became immersed into the *making* practice, were requesting additional time and permission to continue working on their projects rather than to attend the next courses that day. Bound by the formal school legislation, these requests could not always be easily fulfilled; only once, visual programming tasks related to the eCraft2Learn projects were implemented in the context of the ICT course. Voluntarily, some students dedicated their daily school breaks to make progress with their eCraft2Learn projects. One group that was working on a DIY automobile decided to work also extra hours at home in order to test more complex functionalities. The school teachers supported this decision and in a way the *making* practice spanned through their daily lives.

Sharing in the formal pilot site

The sharing of the *making* projects and related experiences with others was considered of great significance by the school teachers. Sharing took place in the class, in the form of tips and advice exchange among the students during the artefact construction. Due to time limitations, the organised sharing of the current status of the work in the class for all the groups was not always feasible. Recognising the importance of sharing, the teachers encouraged the students to participate in school events and to showcase their work in the school community and the wider public. In this light, the students were invited to come together and to share what they had created in well attending events such as the Athens Science Festival 2018, the 'Schools in Creative Moments' Panhellenic Event, the STEM night celebration in a nearby school complex and more.

Figure 1: Students from the 1st EPAL of Korydallos at the eCraft2Learn event in Athens Science Festival 2018 (left) and the STEM night celebration (right).

The active participation in events, the interaction with people of all ages and varying professional backgrounds was considered as a good practice with significant learning benefits for the students. An additional way to share their work was through their social media; the students and the teachers were observed to take pictures of the different stages of the artefact construction and their making experiences and to upload them in their social media accounts.

The roles of the teachers

The tension between the open nature of the eCraft2Learn initiative and the formal school environment was evident also on teachers who initially were struggling at finding their way into coaching. In this unique making environment (open as the *making* culture imposes, but bound by the school formalities), they soon realised that there is neither need to have answers for every single question that emerges, nor to continuously pass along knowledge to the students as the "sage on the stage". As the sessions were progressing, they became more comfortable with their new role, stepping aside and letting students work through challenges and make discoveries for themselves. They smoothly took the role of the mentor, pointing in the direction of knowledge.

At the same time teachers were also acting also as co-makers, sitting next to the students, trying out together different approaches towards problem solving, searching for information and providing useful explanations when needed (i.e. the supported a lot students' understanding of electrical circuit making and programming concepts).

In addition, they were the ones that were securing access to all the necessary eCraft2Learn tools, effective use of the space and pinpointing resources and material that could be used to support the computer-supported artefact construction. As it has been also mentioned earlier, they significantly supported the generation of ideas, especially in the beginning through given topics for projects, as they had realised that the students were not ready at that time to take that specific initiative. As they watched them growing more confident, they discreetly let the space for ideation to the students.

The teachers were also highlighting the importance of making something shareable, looking for opportunities to present the projects in school events or other well attending festivals, communicating also this need to eCraft2Learn implementation team.

Lastly, the teachers were participating in the evaluation procedures (supported by the local eCraft2Learn implementation team). These mainly refer to the periodic completion of teachers' diaries after each eCraft2Learn session. Given the limited available time, the teachers decided to fill in the teachers' diary forms after school hours (when needed) in order to allow more time for the *making* practice and to avoid completing them in rush. Providing information for all the groups and the way these groups were progressing was considered a challenging task. More precisely, in the making space lots of *making* processes were on, several creative risks were taken at the same time and the teachers were shifting frequently their roles from facilitators of the learning practice to co-learners aside the students. The school teachers recognised many benefits in the use of the learning analytics tools, but the review of the recorded data due to the aforementioned reasons was not feasible to take place during school hours. Quick reviews took place during the 2nd pilot, but they had to be carried out in haste. During after schools hours, the teachers had more time to meaningfully go through the recorded data and to spot needs and possible calls for remedial actions from their side.

2.2. Informal Pilot site

The context

The informal eCraft2Learn lab was established in the Technopolis City of Athens (Greece), a former Gas Factory that was restored to an industrial and cultural park. The Technopolis City of Athens is a hub of cultural and educational events and focal point in the cultural identity of Athens. A wide variety of events are held in Technopolis every year: music, dance, theatre and performing arts, plastic and applied arts, educational programs for children and youth, entrepreneurship and temporary exhibitions, attracting over 600,000 people annually. It is centrally located in Athens and well accessible. All these make it an ideal place for hosting the eCraft2Learn initiative.

The lab was set up in the 3rd floor of a former industrial building, the Gas Water Tower. The old machinery remained in the place creating an inspiring scenery with strong conceptual symbolism to *making* and engineering practices.

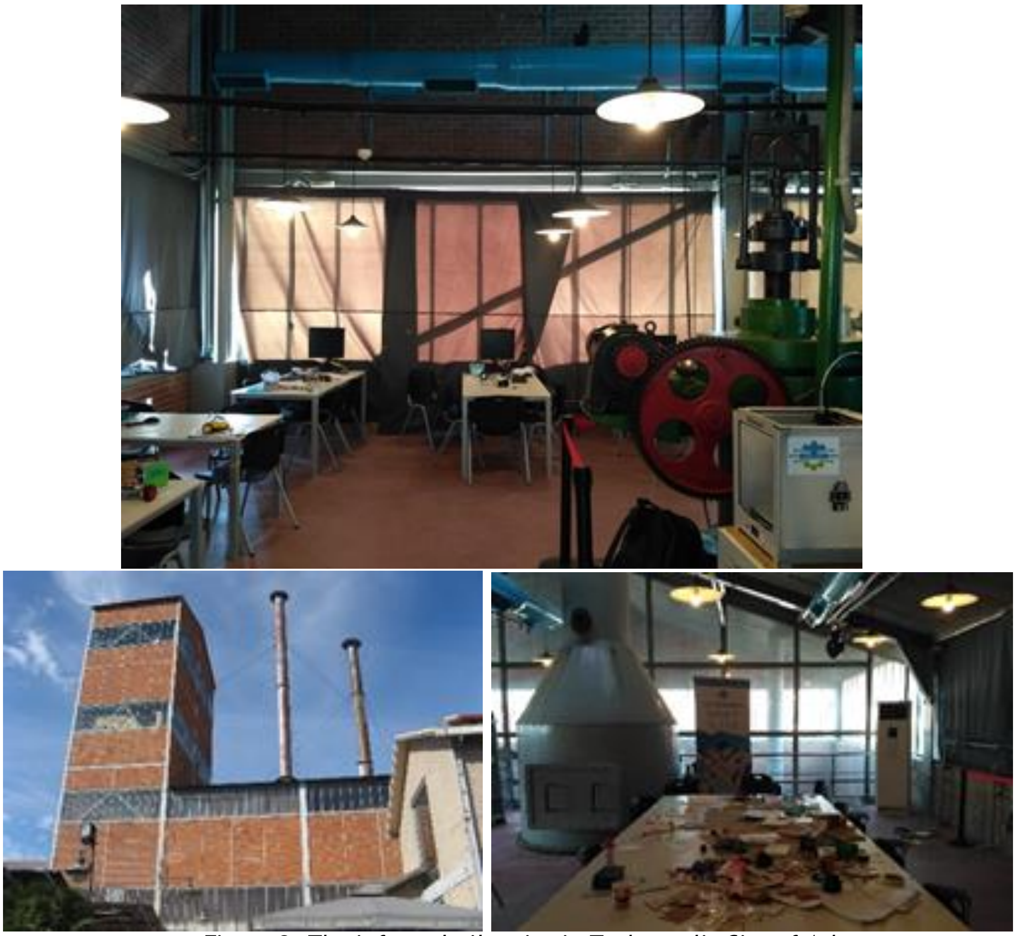


Figure 2: The informal pilot site in Technopolis City of Athens

An open invitation was distributed to the school community by Edumotiva and Technopolis' channels. No student was excluded from the selection process and the group was formed in an ad hoc fashion. The only criteria set were related to the age of the students. In addition, it was also important to us that both genders to be represented in the group. Another limitation was related to the maximum number of students that could effectively fit in the room, which was set to 30 students. The students that formed the final group came from different public schools in the region of Athens, few from private or experimental schools and few others from the Network of Children Rights. The Network of Children Rights is a non-governmental and non-profit organization that aims at improving the quality of life of children from vulnerable groups such as children of immigrants, refugees, repatriates, sick children and children in care or young offenders' institutions by offering them the pleasure and feeling of achievement that come as a result of team effort and group initiative (more information can be found at: https://ddp.net.gr).

Organizational issues

The 1st pilot round was conducted with 24 students from 13 to 17 years old. The same number of students participated in the 2nd pilot round.

The teachers that supported the eCraft2Learn learning initiative were the ones that had received training (see D5.2) by the eCraft2Learn implementation team. During the 1st pilot round 6-8 teachers were active in the eCraft2Learn lab undertaking the role of the coaches. During the 2nd pilot round 4-5 teachers were active in the eCraft2Learn lab.

The 1st pilot round lasted approximately 30 hours and the 2nd pilot round approximately 20 hours. The duration of the 2nd pilot was shortened due to two main reasons; a) the students being more familiar with the eCraft2Learn tools and thus they entered directly into the *making* process working on their own projects (see section 4) and b) most of the students had already scheduled Summer plans (i.e. family vacations, enrolment in Summer Camps and more)

The following table summarizes the key information regarding the 2 pilot rounds in the Greek informal pilot site.

Table 3: Information about the Greek informal pilot site

	Greek informal pilot site	
	1st pilot round	**2nd pilot round**
Total participants	24 students (13-17 years old)	24 students (13-17 years old)
No. of teachers	6-8 per class	4-5 per class
Team work approach	Work in groups of 3-4	Work in groups of 3-4
Time	3 hours every Saturday	3-4 hours every day for a week
Total duration	November 2017- February 2018 Approx. 30 hours	End of June 2018 Approx. 20 hours

Icebreaking and setting the 'didactic contract' in the informal pilot site

The 1st session started with icebreaking activities, the setting of the ground rules and the elaboration of the process which the students will go through. Given that the students and the educators at the informal site did not know already one another, part of the first (1st) session was dedicated to **ice breaking activities**. These activities were selected in advance by the teachers with the aim to activate the necessary mechanisms for the "group-development process" and the establishment of a positive and warm atmosphere.

In the context of the icebreaking activities, the students were encouraged to form a circle and introduce themselves, to talk about their hobbies and interests; through playful techniques were also invited to have short one-to-one conversations. Noteworthy, the teachers took also part in the icebreaking activities and the discussions. The formation of the groups was partly based on these discussions and was partly random. These discussions were also seen as important steps towards team bonding and good relationship establishment.

Figure 3: Icebreaking activities in the informal pilot site

In total 8 groups were formed with 3 to 4 students each. The structure of the groups was a matter to change; for example, some reasonable requests coming from the students for group enhancement were carefully considered and accommodated by the teachers. Action was also taken so as not to have groups consisted all of boys and others all of girls.

During the 1st session, at group level focus lied on creating a set of rules that will reflect the accepted behaviour in the group and in the eCraft2Learn lab, for both educators and students. The teachers considered that the best way to create a set of rules was to decide on them as a group. It was important to ensure that the appropriate rules have been set for establishing a positive atmosphere for peer learning, smooth project deployment, ideas and experiences sharing. The discussion focused on the following topics: group/classroom behaviour, the importance of sharing and ways to support it, the use of the equipment, storage/uploading/downloading of files, lab safety rules.

The discussion about lab safety rules was re-visited as the sessions progressed (i.e. before students' involvement into 3D printing tasks, a discussion was raised regarding possible hazards, good practices and forbidden actions related to the 3D printer).

The icebreaking activities and the setting of the 'didactic contract' was followed by the exploration of the lab equipment at group level. Supported by their teachers, the students set up their working stations and carried out their very first steps into electrical circuit making using Tinkercad circuits simulator. The familiarization of the students with the available tools, technologies and resources was continued through their engagement in the eCraft2Learn projects.

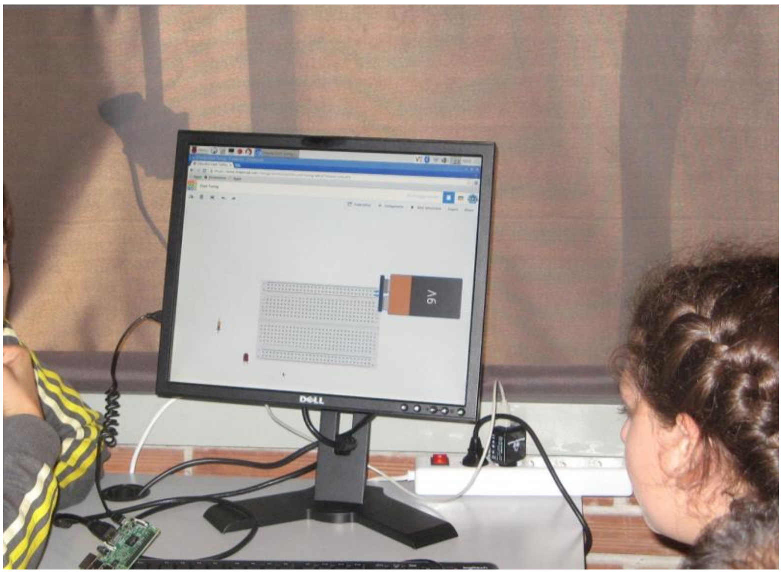


Figure 4: Familiarization through Tinkercad Circuit Design

Implementing the eCraft2Learn methodology towards computer- supported artefact constructions

Like it happened in the formal pilot site, the ideation was considered a challenging process and the teachers especially in the beginning supported it a lot. The first projects that the students involved into were proposed by the teachers, who exploited the list of the indicative scenarios introduced during their teacher training (see D5.2). In a similar way to the formal pilot site practices, easy to start with projects were selected with the aim to smoothly familiarize the students with the available tools and the kind of artefacts that can be created. As the sessions were progressing the teachers were reducing the level of support on this matter encouraging choice in project selection.

More precisely, the students were being asked about any possible idea that they would like to implement in the near future. Noteworthy, through their diaries (see D5.4), they were also encouraged to periodically document their ideas for new projects. Their responses on this matter were not very enlightening in the beginning. However, as they were becoming more familiar with tools and the technologies, they started expressing interest in working on specific or thematic projects. In December, being in Christmas mood, some teams were noticed to give a Christmas touch to their artefacts and discuss the implementation of Christmas-related artefacts (see section 4.5). The review of the students' diaries brought also additional interesting ideas into focus: many students expressed an interest in creating a moving robotic artefact that can be controlled by them.

Some of their ideas were general while some others more specific. For example, they were referring to *robots that move and change colours, to solar cars, vehicles with many sensors, cars that move around and follow commands and more*. Building upon this interest, the teachers supported a relevant project for DIY automobiles (see section 4.6) providing students with the freedom to personalise their automobile, to address to it specific behaviours and functionalities and to give it the form that they liked.

Figure 5: The students are filling in their diaries in the end of the session

During the 2nd pilot round, most of the projects came directly by the students. Noteworthy, one group (the group members of which met one another during the 1st pilot round) mentioned that they arranged a meeting in a cafe before the beginning of the 2nd round to get together and to discuss some ideas that had emerged for new computer-supported artefact construction. Noteworthy, this was another encouraging sign that the eCraft2Learn practices entered into learners' daily life in a meaningful way.

The following table presents the projects that were carried out in the Greek informal pilot site, during the two pilot rounds. As one can notice, some ideas for projects were proposed by the teachers whereas some others came directly from the students (mainly during the 2nd pilot round) either as an extension of an existing project topic or as a completely new idea. During the 2nd pilot round, a group expressed the interest to work on a DIY automobile that could be remotely controlled. Noteworthy, that specific group was based on previous experiences addressing to the artefact more innovative and advanced functionalities and digging deeper into the tools available the eCraft2Learn UUI (Unified User Interface).

Table 4: The emergence of project ideas in the informal pilot site

Projects	The project idea/topic was suggested by the teachers	The project idea was extended by the students resulting to a new project or an advance one	The project was building upon another project that had been earlier implemented	The project idea came from the students
1st pilot round				
The Lighthouse project (see section 4.1)	x	x		
The Shy Rabbit project (see section 4.3)	x			
The Sunflower project (see section 4.4)	x	x		
Christmas artefacts (see section 4.5)				x
DIY automobiles (see section 4.6)	x	x		
2nd pilot round				
The Voice Driven Face (see section 4.11)	x			
DIY automobiles (advanced ones) (see section 4.6)			x	x
The 3-level security control (see section 4.10)				x
The joypad for controlling a video game (see section 4.9)				x

The generation of ideas was also important during failures; failures were part of the *making* process (i.e. failed prints, artefacts that did not operate properly) and often the students were invited to share their ideas regarding possible solutions for overcoming the emerging problems. The teachers discreetly observed and supported this process; in some cases, teachers' intervention was more dynamic by providing useful explanations (i.e. in making circuitry more transparent, increasing students' understanding of electronics) to help students move forward. Frequently, the teachers were encouraging the group members to bring these ideas in the plenary for the benefit of the whole group. Sharing existing ideas, plans for implementation, problem solving practices and thoughts in group and in the plenary was seen as a process that can significantly boost the generation of ideas for new computer-supported artefact constructions.

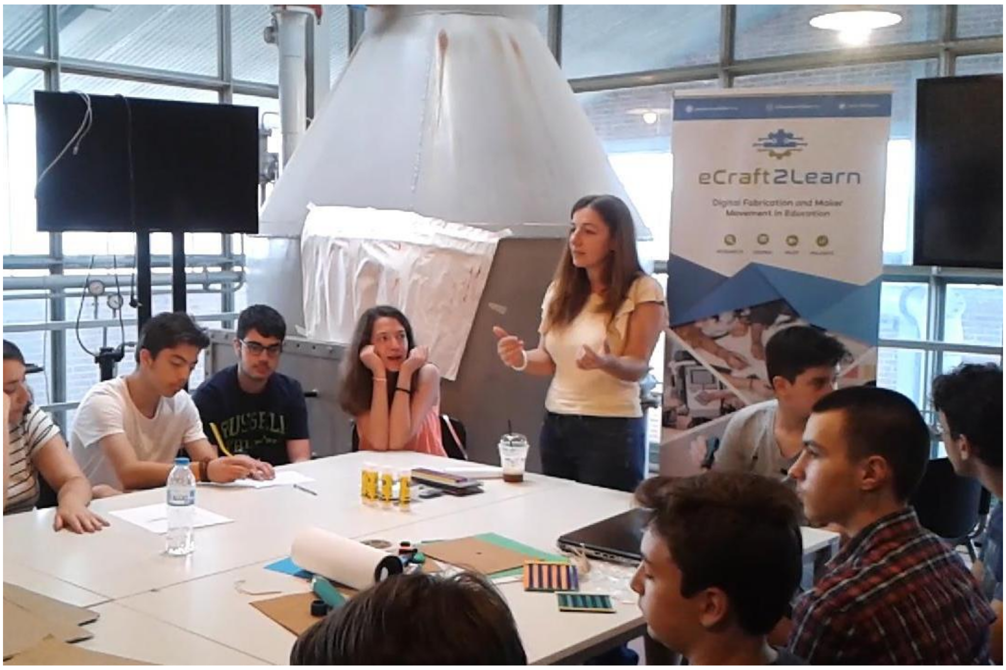


Figure 6: Bringing ideas in the plenary

There was also encouragement towards analysing ideas, breaking down complex activities into sub tasks, keeping notes about STEM concepts related to their project (i.e. electrical circuit making), listing the material that will be needed, sketching the structure of the construction, visualizing the key processes. This was actually the stage of planning that in many cases was embedded in the ideation process, re-visited and creatively re-approached by the groups during the creation of the artefacts and the programming phase. In a way, these practices show how interlinked the stages [2] of the eCraft2Learn methodology are (WP3, D3.1). Most of the groups created paper-based plans while other groups agreed orally on the steps to be undertaken. The release of the updated version of the Unified User Interface (UUI) platform offered students more tools for planning their computer-supported artefact constructions (i.e. eCraft Plan, eCraft TODO tools) during the 2nd pilot round.

Figure 7: List of handcrafting materials for the Sunflower project “Translation from Greek into English: The materials that we will use are: glue, silicon, cardboards, straws, buttons, thin metal wires”

[2] The 5 interlinked and iterative stages are: ideation, planning, creation, programming, sharing

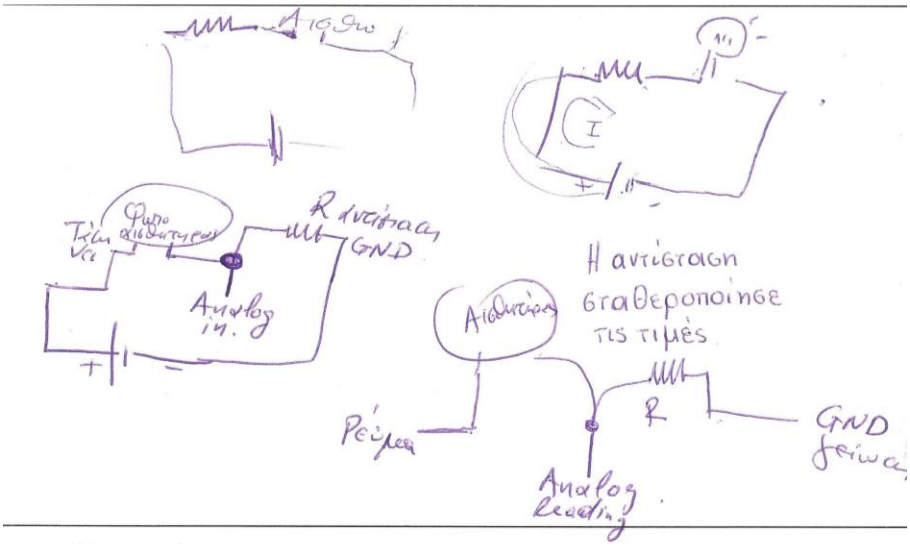


Figure 8: Sketching the electrical circuits for the 'Christmas Artefacts' project

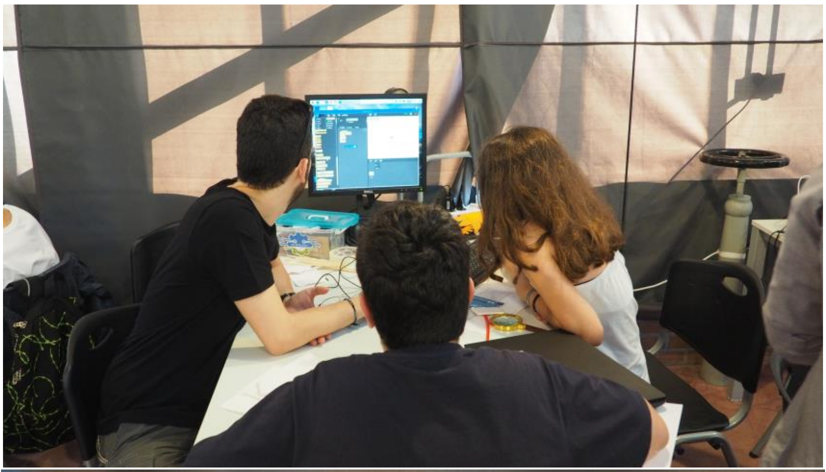
As the sessions were progressing, the students (based on their interests and at their own pace) were engaging more naturally in the creative production of different artefacts. Different projects were going on at the same time, different challenges were calling for solutions, lots of hands-on *making* activities inspired students to dig deeper and to extend their ideas. Moved by the fun of *making*, many students were noticed to stay longer in the eCraft2Learn lab than initially planned.

Figure 9: The making process

Team work, distribution of roles and challenges

Role distribution was also noticed in some teams; some students were in charge of the electrical circuit making, others more into programming, some others were more involved into 3D modelling and handcrafting. The role allocation happened at group level and was not enforced by the teachers.

However, there were few groups where the group members were involved in all the parts of the development of the computer-supported artefact supporting one another. The teachers only intervened in few cases whenever a member of the group was inactive. They were mainly trying to understand the reasons behind the inactivity and to create a situation where through the interaction with the other group members, a role for him/her will emerge. For example, in one of the groups there was a young boy rather introvert who became absorbed by his smartphone applications. The teacher/coach of the team told him that it would be very useful to record the artefact construction process using his smartphone as this will allow the sharing of the work online ensuring greater visibility. The student took happily the challenge and started observing what was going on but (initially) only through his smartphone lense as he was video-recording the process of the construction. Smoothly, he was taken over by the *making* spirit and was noticed to participate more, to express ideas for alternative solutions and become member of the team.



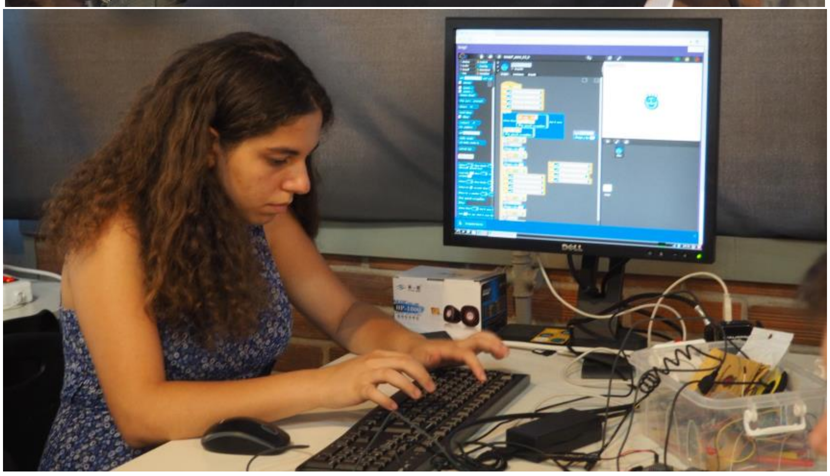


Figure 10: Programming the artefacts

A closer look into the aspect of 'Sharing' in the informal pilot site

The sharing of the *making* processes and the *making* projects with others was considered of great significance in the informal pilot site in Greece. The teachers encouraged all the groups to share the current status of their work in the end of almost each session (see relevant video in section 5), to talk about the processes that they went through and their future plans. *In the informal pilot site (unlike it happened in the formal pilot site), the time factor did not obstruct this practice.*

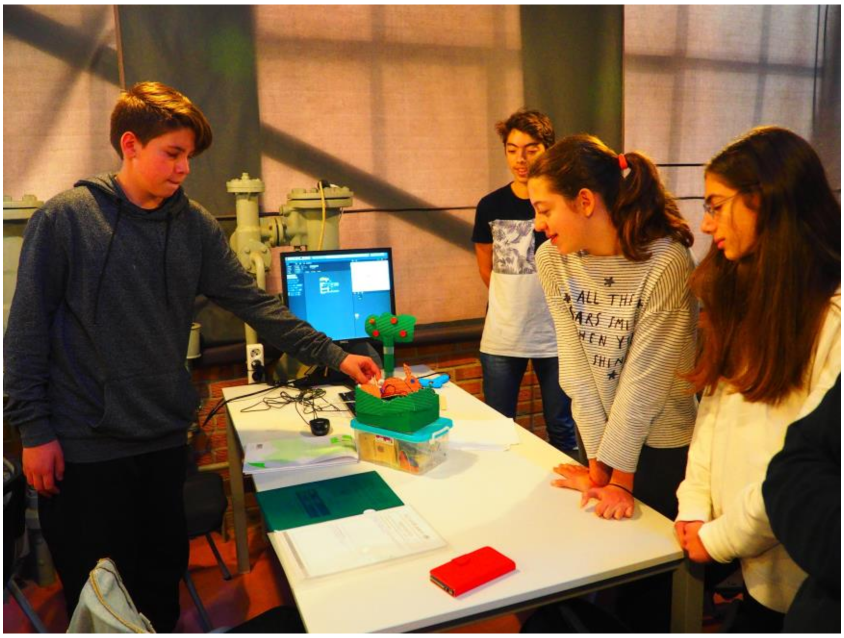


Figure 11: Presenting the current status of the work to the whole group

In addition, the groups were encouraged to showcase their work in the school community and the wider public. In this light, the students presented their projects in the Athens Science Festival 2018 and interacted with people of all ages and from varying scientific backgrounds as well as with other groups of students that participated in the festival either as exhibitors or visitors (see relevant video in section 5).

Figure 12: Students from the informal pilot site in the eCraft2Learn event at Athens Science Festival 2018

The students and the teachers were also noticed to record their work using their smartphones or cameras. At a later stage, some of this material was uploaded by them in their social media accounts. UUI tools were also used to share parts of the artefact construction. Although not practiced by all the groups, some groups encouraged by their teachers were seen to upload their 3D models (i.e. the nameplates for the DIY automobiles) from Tinkercad to Thingiverse Community (see relevant video in section 5).

The roles of the teachers

The description above revealed already many interesting aspects of the role of the teachers in the informal making space. Given the different ages in the group, their contribution on the formation of the teams early in the beginning and their remedial actions were also of great significance. The teachers were seen as supporters of the learning process, co-makers, boosters of the collaborative work, the discussion and the sharing at team level and beyond.

However, most of them adopted smoothly these roles dealing with their own thoughts and concerns at their own pace and in some cases guided by the students. As documented also in D5.2, especially during the 1st pilot round, the teachers were quite concerned about their self-image in the class. Their concerns revolved around the question: ‘What if we do not manage to support the students? What if we cannot answer their questions’. As long as they started seeing the eCraft2Learn lab as a making environment and themselves as co-makers, co-designers and facilitators of the learning process, their stress smoothly eliminated allowing them to stand by the students as coaches.

The teachers supported significantly the generation of ideas prompting for relevant group discussions and existing project ideas extension. In addition, they boosted a lot the ‘Can-do’ attitude, sharing their enthusiasm with the students and creating an atmosphere conducive to learning.

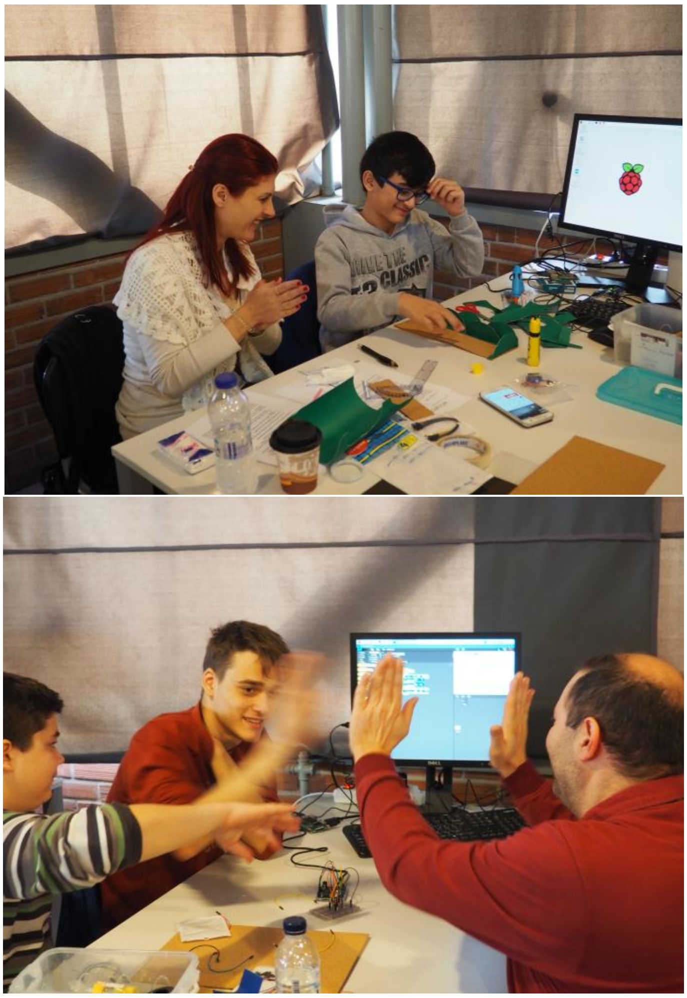


Figure 13: Empowering students and sharing feelings of excitement

Last, the teachers were participating in the evaluation procedures (supported by the local eCraft2Learn implementation team). As discussed above (see section 2.1), these mainly refer to the periodic completion of teachers' diaries after each eCraft2Learn session (WP5, D5.4). The teachers preferred to fill in their diary forms after the eCraft2Learn session, at their own pace, when at home. Some teachers were noticed to keep notes during the workshop with the aim to transfer them into their diary forms later on. The news about the release of the learning analytics tool pleased the teachers. However, they soon realised that it was very challenging to use the learning analytics tools while the making and the learning process was on. However, when there were many teachers/coaches in the eCraft2Learn lab, the review of the recorded data in the learning analytics platform could happen, but it required good synchronization among them. In general, they all agreed that it was more practical to go through the recorded data after the workshop.

Figure 14: The teachers in action

3 DESCRIPTION OF SMALL- SCALE CASE PILOTS IN FINLAND

3.1. FORMAL PILOT SITES

The context

In Finland, the formal pilots were held in two schools in the city of Joensuu: Pataluoto and Lyseo secondary schools. Three student classes from Pataluoto and one from Lyseo participated in the 1st round of pilots. From Pataluoto two new student classes and from Lyseo the same class of students took part of the project in the 2nd pilot round.

Organisation of the projects

During the 1st pilot round, three classes planned to carry out their school subject topics through the eCraft2Learn learning ecosystem. However, quickly after starting the project with one student class, a teacher received a request from another student class to be able to take part in carrying out their school subject topics through the eCraft2Learn learning ecosystem as well. Consequently, a total of four student classes with 57 students participated in the 1st pilot round. Three classes with 49 students took part in the 2nd pilot round. All participating teachers had received the teacher's training before the 1st pilot round and between the 1st and 2nd pilot round.

School hours were set as the teachers had their lessons for the specific subject matter with each participating student class. However, during both the pilot rounds there were one student class whose projects consisted of 3-4 school hours that were organised altogether another. Teachers saw the advantage of these long sessions as students could focus on the work in great extent and achieve the 'flow' of working.

The pilot projects took approximately 18 hours in the 1st pilot round and 9 hours in the 2nd pilot round. The duration differed a lot between the student classes and therefore the durations are not comparable between 1st and 2nd pilot rounds. Some teachers set limits to the students' working time to be used for the eCraft2Learn activities according to the specific lessons from the school curriculum. Other teachers were ready to use as many hours as needed to finish the student projects as they saw it important to give enough time for student to use their creativity and to experiment with the trial-and-error process. Teachers stated that it is necessary for students to feel accomplishment with finished projects.

Teachers were aware of the characteristics of project-based learning, and it took more hours to go through a specific subject matter and topic using the eCraft2Learn learning ecosystem than using traditional school work. However, teachers did not see this slower learning on the subject matter itself as a problem as, unlike in traditional school work, students improved a wide variety of skills including digital literacy, creative thinking and problem-solving skills. All project work was naturally interdisciplinary and students spent significant amount of time in the wood and metal craft rooms as well as in the arts classroom. The participating teachers saw this as a perfect opportunity to collaborate with their peers and plan the projects together for longer period. In this way, the time investment from a single subject matter was eased as multiple subject joined together to work on the projects.

Table 5 presents the key information regarding both pilot rounds in the Finnish formal pilot sites.

Table 5: Key information regarding the Finnish formal pilot sites

	Finnish formal pilot sites	
	1st pilot round	2nd pilot round
Total participants	57 students (4 classes, 13-16 years old)	49 students * (3 classes, 14-16 years old)
No. of teachers	1-2 per class	1-2 per class
Team work approach	Work in groups of 2-6	Work in groups of 2-6
Time	1-3 school hours per week	2-4 school hours per week
Total duration	November 2017- early March 2018 Approx. 18 hours	April 2018- May 2018 Approx. 9 hours

** one class of 16 students participated both in the 1st and 2nd pilot round*

Implementing the eCraft2Learn methodology towards computer- supported artefact constructions

Following the eCraft2Learn initiative, problem solving and creativity skills were developed throughout the hands-on projects. Students worked actively and with great motivation in all pilot projects by distributing roles and using each team members' strengths when working collaboratively towards the same visions and ambitious goals. Some students who quickly developed competence in basis of programming, provided their help to other teams in their programming issues from either students' own or teacher's initiatives. Most of the students had very little previous knowledge about electronics or programming but they quickly acquired new knowledge, gained confidence in an unfamiliar field, and created masterpieces. Teachers let students to have the main role in the classroom and fostered their self-regulation skills with multiple instructional strategies.

Although the student classes had different teachers, all projects were following a similar general structure in working, as per the teachers had practiced during the teachers' training and following the eCraft2Learn pedagogical framework. First, teachers presented the root topic that students would start investigating and elaborating, attempting to create a representation or solution for the proposed question or topic. During the 2nd pilot round teachers also introduced the Unified User Interface (UUI) for students as the UUI developments were ready and allowed the platform to be used fully during the 2nd pilot projects (it had also been used during the 1st pilot rounds albeit partially). After the introductory session students started ideating and planning their projects according to the proposed topic. Simultaneously with the ideation process, students were familiarised to the technical core of the project with hands-on activities, starting to create and test programs with Arduinos, and moving gradually from easier to more challenging tasks. The artefact creation process was iterative throughout the projects as every stage of the eCraft2Learn pedagogy was seamlessly connecting to each other. The artefact creation culminated with most student groups sharing their projects via videos or presentations in different dissemination activities.

All projects that were carried out in the Finnish formal pilot sites are shown in the Table 6 per pilot round. In the 1st pilot round, class number one took part of the first photosynthesis project, while classes two and three had projects about security in society and class number four did the photosynthesis project two.

Figure 15: Student teams presenting their work to the NASA astronaut after the 1st pilot round

In the 2nd pilot round, the same class number four had a solar system project, class five had the Cold War project and class six took part in the geographical phenomenon project. In the first photosynthesis project, a biology and a mathematics teacher joined their efforts and were co-teaching the class. A social sciences and history teacher held both the security in the society and the Cold War projects, and a biology and a chemistry teacher co-taught both the second photosynthesis and the solar system projects.

Table 6: The emergence of project ideas in the Finnish formal pilot sites

Projects	The project idea/topic was suggested by the teachers	The project idea/topic was extended by the students resulting to a new project or an advance one	The project was building upon another project that had been earlier implemented	The project idea came from the students
1st pilot round				
The Photosynthesis project 1 (see section 4.12)	x	x		
Security in society project (see section 4.13)	x	x		
The Photosynthesis project 2 (see section 4.12)	x	x		
2nd pilot round				
The Cold War project (see section 4.15)	x	x		
The Solar System project (see section 4.16)	x	x		
Geographical phenomenon project (see section 4.17)	x	x		

3.2. Informal Pilot Sites

The contexts

The SciKids science club (1st pilot round)

The 1st round of pilots was carried out together with the SciKids after-school science club at the University of Eastern Finland premises. The students participating in the pilots were familiar with the use of technology although the pedagogical approach to digital fabrication and *making* was new to them and theirteachers/educators. The participant students were recruited voluntarily and carried out the pilot activities as part of the SciKids club activities.

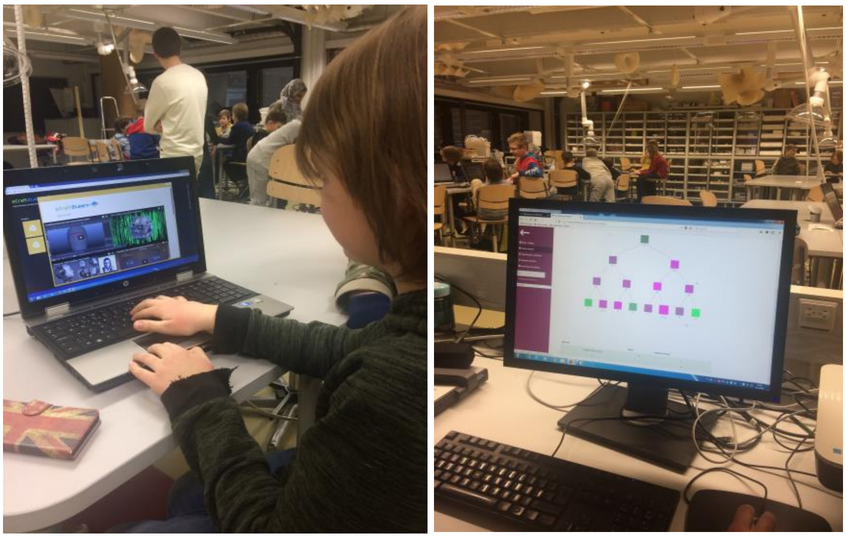


Figure 16: The SciKids Science Club at Luma Centre, University of Eastern Finland

The Light-a-bot Makerspace (2nd pilot round)

There were difficulties starting the 2nd pilot round in informal settings, as it was not possible to carry the activities out during summer, due to the summer holidays. Moreover, as for this school year (Autumn semester, 2018) the age group of the students that were expected to participate from the SciKids after-school club was much younger than the students that had previously participated during the 1st round of pilots, and many students were not available during the time that the pilots were scheduled. Therefore, students were recruited from a local secondary school to join the after-school activities of the informal pilot activities. The place of the 2nd pilot round in informal settings also change. The activities were carried out in the newly established Light-a-Bot Makerspace in Joensuu. The teacher in charge of establishing this makerspace took part during the teacher training as well as during both formal pilot rounds of the project and took inspiration to disseminate the ideas of digital fabrication and *making* in education alongside the eCraft2Learn project. The Light-a-bot Makerspace is located in a newly renovated Botanical Garden in the city, aiming at becoming a place where the pervasiveness of the technology can be appreciated amid tropical vegetation.

Figure 17: The Light-a-bot Makerspace at Botania, Joensuu

Organisation of the projects

15 students up to 13 years of age participated in the 1st pilot round through the SciKids science club. During the 2nd pilot round, 15 students up to 16 years of age were recruited. Three to four educators/teachers were guiding the students in both pilot rounds. In the 1st round, participating educators were master students in computer science, thus they had a broad experience on working with different kind of electronics, programming languages and other technologies. The 2nd round included teachers mostly with a strong pedagogical background, although they also had competence with electronics and programming within the eCraft2Learn ecosystem.

The projects in the 1st pilot round took approximately 9 hours to complete and in the 2nd round 8 hours. As the time was limited, the piloting sessions were focused so that student teams created one project during their work.

The key information regarding both pilot rounds in informal settings is provided in Table 7.

Table 7: Key information about the Finnish informal pilot sites

	Finnish informal pilot sites	
	1st pilot round	**2nd pilot round**
Total participants	15 students (1 class, 8-13 years old)	15 students (1 class, 14-16 years old)
No. of teachers	3-4 per class	3-4 per class
Team work approach	Work in groups of 2-4	Work in groups of 2-4
Time	2 hours per week	2 hours per week
Total duration	February 2018- March 2018 Approx. 9 hours	October 2018 Approx. 8 hours

Freedom of the work in informal settings

In the informal context, work was not bound to any specific curriculum; therefore, the project topics were set more freely. It was noticed that students in the informal pilots had much less challenges with ideating and planning their projects than in the formal sites. Students were iterating their ideas and coming back to their plan constantly by improving the original idea. Although students were able to choose all preferred tools, materials and methods of work also in the formal site, a bigger degree of freedom was seen throughout the informal pilot work. Teachers noted that the effect of outside school location is vast in student learning and boosts creativity when there is not such a big pressure of progressing and achieving academically good results. In general, students in the informal site were truly engaged in the *making* and eager to implement new projects before they even had finalised the first ones.

Time constraints

The time issues due to organisational reasons were affecting both pilot rounds. However, the work itself was not pushed and students did not need to work under pressure as they went iteratively through all the stages in the eCraft2Learn pedagogical framework. The vast majority of student teams could finish their projects in the set time limits and the created artefacts were brilliant.

As the eCraft2Learn ecosystem was new to all participating students, the broad topics on which the students needed to work were presented by teachers. However, students were encouraged to narrow down the topic to find an idea that was interesting for the students to develop. Students could also grab something from the proposed topics and extend any existing idea to create their own. When searching the project idea, students' learning was differentiated and personalised which did not only led to unique projects but also to increase student motivation and allowed students to make creations that were meaningful to them. Table 8 demonstrates all projects that were implemented in the Finnish informal pilot sites per pilot round.

Table 8: The emergence of project ideas in the Finnish informal pilot sites

Projects	The project idea/topic was suggested by the teachers	The project idea was extended by the students resulting to a new project or an advance one	The project was building upon another project that had been earlier implemented	The project idea came from the students
1st pilot round				
Robot Head project (see section 4.14)	x	x	x	
2nd pilot round				
Interactive art project (see section 4.18)	x	x		
Smart home project (see section 4.19)	x	x		

Work processes in informal settings

Student teams in both informal pilot rounds were very focused and engaged in their own work but did not interact much with other teams (see Figure 18). Nevertheless, one of the teachers in the second pilots argued that students were sharing constantly inside their teams and also when explaining their work for the teachers and educators. However, sharing among teams should be encouraged as it may help students for example to see their ideas and plans from a new perspective, to get ideas and constructive feedback and to improve their presentation skills. More interaction between the different teams was noticed in the formal than in the informal pilot site.

Figure 18. Group work during informal pilots. There was little interaction between groups.

Self-regulation

During the 1st informal pilot round that the skill level of the students was very high despite of their young age as the participants were members of the after-school science and technology club and have been involved in programming and *making* activities with different electronics for many years. These participants were highly self-regulated, independent and patient learners who only needed few hints and instructions about how to proceed. Children were very keen on testing and using electronics, and were not afraid of exploring. They also had ambitious plans such as creating a robot that shoots marshmallows. During the 2nd pilot round students were also very interested and engaged in their projects, and came up with many creative ideas, although they did not have previous experience with electronics or programming. The ideas shown by the teacher worked just as inspiration to demonstrate what might be possible to do, but students considered very nicely the possibilities and created their own ideas.

Through trial and error testing the students concretized their understanding and expanded their initial knowledge base. For example when they learned how to wire one LED, students created their own solution for wiring three LEDs. The students did not hesitate to ask questions or help, showing that they were very involved in the process and were excited and innovative in their work. However, it was noticed that questions were not deeply related to the functioning of electronics or the theory behind programming. When explaining the principles of electronic circuits and programming, it could be seen that these were relatively difficult for many students to understand. It is relevant to ponder, how much time would it take to make students to comprehend these principles more deeply, or how much do students need to understand. Thus, what the meaningful ratio of white box and black box information is so that students' self-regulation is facilitated.

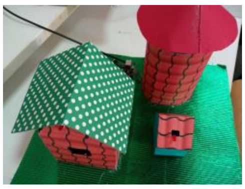
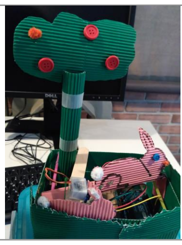
Failure as a learning opportunity

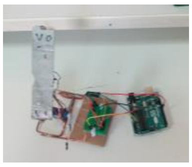
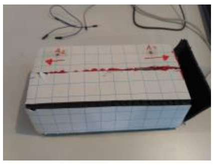
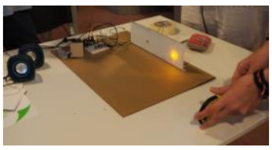
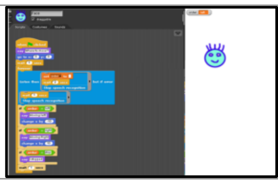
As during the 1st pilot round some of the groups' 3D printed models did not turn out how they were supposed to, students developed their problem solving and creativity skills as they were trying to solve the issue by either making a new 3D model or trying to make the creation with other materials. Moreover, in both pilot rounds, the tasks had to be challenging enough and the tools had to offer enough opportunities for different creations to keep the students motivated throughout the whole project. If the activities were not challenging enough the younger students got distracted relatively easily and started shifting their focus away from the actual tasks, and thus requiring more intervention from the educators. This reflects on finding a good balance between the level of difficulty of the activities and amount of failure that the students may bear in order to make the entire experience an enriching learning opportunity.

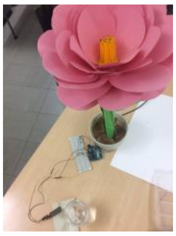
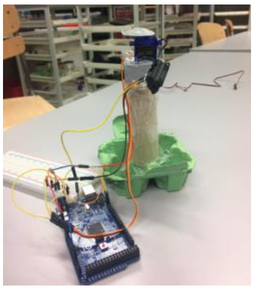
4 THE ECRAFT2LEARN PROJECTS THAT WERE IMPLEMENTED

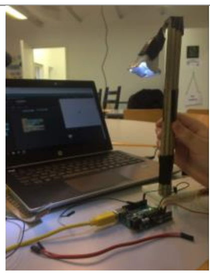
In the context of the two (2) pilot rounds in Greece and Finland, a number of eCraft2Learn projects were implemented. In the table below, these projects are listed together with short descriptions. Noteworthy, some projects have been approached from several teams; thereby a number of different computer-supported artefacts have been created under the same project idea or topic. The projects are interdisciplinary in nature bringing together a combination of different disciplines from the field of Science, Technology, Engineering, Arts and Math (STEAM).

Table 9: List of the projects that were carried out in Greece and Finland

Title of the project	Representative picture	Brief description of the project
No1: The lighthouse project		The lighthouse that blinks in dark For more see **section 4.1**
No2: The small village project		Few buildings together constitute a small village with lights that blink during the night and at various rates For more **see section 4.2**
No3: The shy rabbit project		The animal that reacts at loud sounds For more see **section 4.3**

Title of the project	Representative picture	Brief description of the project
No4: The sunflower project		The phenomenon of phototropism and the case of the sunflowers. For more see **section 4.4**
No5: Christmas artefacts		Several computer-supported artefacts that reflect the Christmas mood. For more see **section 4.5**
No6: The DIY automobiles		Several types of DIY automobiles with simple and more advanced functionalities. For more see **section 4.6**
No7: The solar panel project		An artefact that simulates the movement of solar panels and can be used to initiate discussion about solar energy. For more see **section 4.7**
No8: The 3D bridge project		A bridge structure with 3D printed parts. For more see **section 4.8**
No9: Video game joypad		A joypad for controlling a video game made in Scratch. For more see **section 4.9**
No10: The 3-level security control system		A security system for a museum with three control zones. For more see **section 4.10**
No11: The voice Driven Face		A face that follows voice commands. A project that is based on AI (Artificial Intelligence) programming. For more see **section 4.11**

Title of the project	Representative picture	Brief description of the project
No12: Photosynthesis project		A representation of photosynthesis (especially the reactants, light, water and CO_2, in the photosynthesis process). For more see **section 4.12**
No13: Security in society project		A security system where the designed precious item is protected from being stolen with the created security system around the item. For more see **section 4.13**
No14: Robot Head project		A robot that moves its head when someone is approaching it or when it notices too much light. For more see **section 4.14**
No15: The Cold War project		Projects created around the topic of Cold War. Student chose a specific event of the Cold War and built a project about Korean War or Cuban Missile crisis, for instance. For more see **section 4.15**
No16: Solar System project		Different projects developed around the Solar system topic in which craft materials, electronic components and AI programming were combined. For more see **section 4.16**
No17: Geographical phenomenon project		A project to represent a geographical phenomenon. Projects included interactive maps where flat maps were enriched with geographical information through AI programming. For more see **section 4.17**

Title of the project	Representative picture	Brief description of the project
No18: Interactive art project		An artwork that is enhanced with technology. In this project arts and visual expression worked as a starting point and the work was initiated through arts. For more see **section 4.18**
No19: Smart home project		A project about a smart home application with remote control or security systems for instance. For more see **section 4.19**

As it has been explained earlier, the ideas for the topics came from the teachers (either as easy to start with projects or as topics that are in line with the school curriculum). Most of them were extended or personalised by the students resulting to new projects and in some cases in more advanced and innovative ones. Some project ideas were clearly building upon projects that had been implemented earlier, transferring past implementations and technical solutions into new contexts. Last, as the sessions were progressing, some teams were seen to take initiatives for implementing their own ideas having the teachers by their side as co-makers.

Table 10: The emergence of ideas for all the eCraft2Learn projects

Projects	The project topic was suggested by the teachers	The project idea/topic was extended by the students (resulting to a new project or an advanced one)	The project was building upon another project that had been earlier implemented	The project idea came from the students
The Lighthouse project	x	x		
The Shy Rabbit project	x			
The Sunflower project	x	x		
Christmas- related artefacts				x
DIY automobiles	x	x	x	x
The small village			x	
The 3-level security control system				x
The Joypad for controlling a video game				x

Projects	The project topic was suggested by the teachers	The project idea/topic was extended by the students (resulting to a new project or an advanced one)	The project was building upon another project that had been earlier implemented	The project idea came from the students
Voice Driven Face project (AI extensions)	x			
DIY automobiles with remote control				x
The solar panel project			x	
The 3D bridge project			x	
Photosynthesis project	x	x		
Security in society project	x	x		
Robot Head project	x	x	x	
The Cold War project	x	x		
Solar System project	x	x		
Geographical phenomenon project	x	x		
Interactive art project	x	x		
Smart home project	x	x		

The aforementioned projects, that were implemented in the formal and the informal pilot sites in Greece and Finland, are described in detail below. The context of each project is described, the time for the construction is mentioned, information about the materialization and the technical part is also documented. Links to videos that showcase the artefact are also provided where possible.

4.1. THE LIGHTHOUSE PROJECT

The Lighthouse project was one of the first projects that were implemented by the students (in the formal and informal pilot sites in Greece). The main task for the students was to look online for information about the functionality of the lighthouses and the built structures and to make their own functional lighthouse that blinks only at dark.

This project was proposed by the teachers as an ideal start towards exploring the available eCraft2Learn tools and technologies and a first simple step towards becoming familiar with visual programming and electrical circuit *making* practices (see also D3.2 and D5.1). A worksheet was also given to the students to support their engagement in the eCraft2Learn process (*available in the Educational Resources, in the Worksheets section in the Unified User Interface*[3]).

The scenario of this project offered students the opportunity to express their creative skills, to involve into handcrafting. Some teams were noticed to make drawings and mock ups inspired by structures of lighthouse buildings that they found online, while some others were making more abstractive or creative designs. The project offered also opportunities for discussion in groups which mainly initiated by the teachers and revolved around the following topics: continuity and change of lighthouses over time, technological and scientific developments over long periods and maritime history.

Figure 19: Different structures of lighthouses created by the students (informal pilot site)

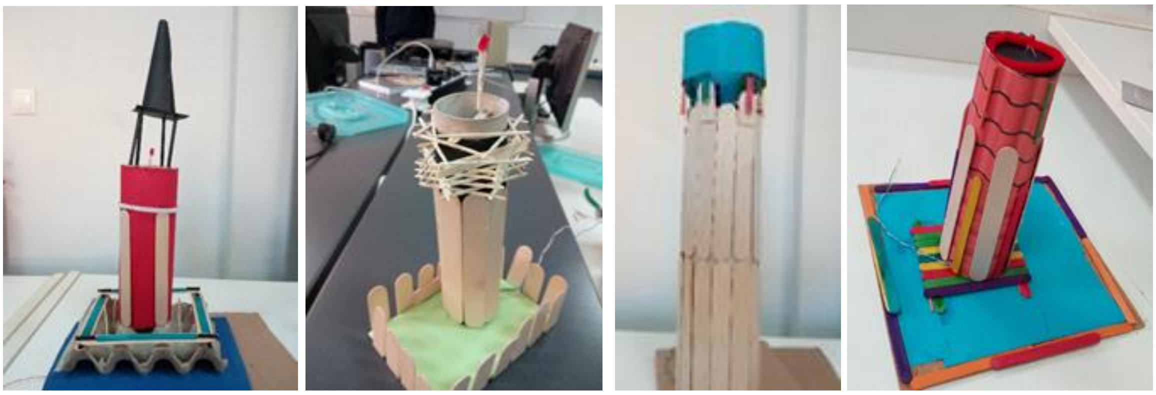


Figure 20: Additional structures of lighthouses created by the students (formal pilot site)

Time allocated

Most of the groups completed the project within 3-5 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the structure
- wooden sticks
- wires and LEDs
- photoresistors, resistors
- Arduino Uno units

Technical details & software used

Students used Ardublock or Snap4Arduino visual programming environments to make the lighthouse LED blinking at a specific ON/OFF pattern. At a second stage, they focused on achieving the blinking

[3] Unified User Interface (UUI): https://ecraft2learn.github.io/uui/index.html#

only at dark. The basic idea from a technical perspective was to periodically poll the photoresistor (available via the analog (A0) input of the Arduino) and compare these readings with an experimentally defined threshold value. Whenever the readings were below that threshold, the Lighthouse LED was set to HIGH and after that to LOW, for several milliseconds, according to the blinking pattern that they had set.

Video: https://youtu.be/tj_HaMKu3eY

4.2. THE SMALL VILLAGE PROJECT

Drawing upon the experience gained in the context of the Lighthouse project, a group of students from the formal pilot site in Greece was noticed early in the beginning to extend the Lighthouse project scenario. Using the recently introduced eCraft2Learn tools, the students modelled a small village with buildings that had lights that were blinking at dark. They were then involved in different experimentations such as:

- controlling the intense of light with a potentiometer
- continuous blinking (regardless the time of the day)
- activating various conditions for controlling the rate of blinking
- achieving blinking only at dark
- synchronizing the blinking in the different buildings
- led lights of different colours blinking every 3 seconds

Figure 21: The small village project

Time allocated

The group completed this project within 2-3 hours

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the structure of the buildings
- wires and LEDs
- photoresistors, resistors, potentiometers
- Arduino Uno units

Technical details & software used
Similar to the technical implementation in the Lighthouse project, the students used either Ardublock or Snap4Arduino visual programming environments to program the Arduino. The focus was on making the LEDs blink according to a specific ON/OFF pattern. They further experimented with achieving this only at dark. They also performed further experiments such as dimming the light emitted by the LEDs. In order to achieve this the LEDs were connected to the PWM capable outputs of the Arduino Uno; these outputs were driven by adjustable values provided by a potentiometer (e.g., connected to the A1 input). Furthermore, several wiring configurations were tested so as to achieve synchronised light effects for all the buildings of the village.

Video: https://youtu.be/pmM_vw6Mw18

4.3. The Shy Rabbit Project

The Shy Rabbit project was implemented in the informal pilot site in Greece. It was the second project that was carried out in the informal pilot site in Greece and the idea for this project came from the teachers who felt that they should boost the ideation stage by proposing simple projects that will allow students to explore additional eCraft2Learn tools and later on to build on the knowledge gained. The main task for the students was to look online for information about the reactions of animals (such as the rabbit or others) at loud sound and to transfer this behaviour in their own computer-supported artefacts.

The project was considered ideal for novices as it was further introducing them into sound sensors and related programming concepts. A worksheet was also given to the students to support their engagement in the eCraft2Learn process for this specific project (*available in the Educational Resources, in the Worksheets section in the Unified User Interface*[4]).

The scenario of this project offered students with opportunities to express their creative skills and to involve themselves in handcrafting. Some teams were noticed to make drawings, to break down the project into smaller tasks and to plan the next steps to be undertaken.

[4] Unified User Interface (UUI): https://ecraft2learn.github.io/uui/index.html#

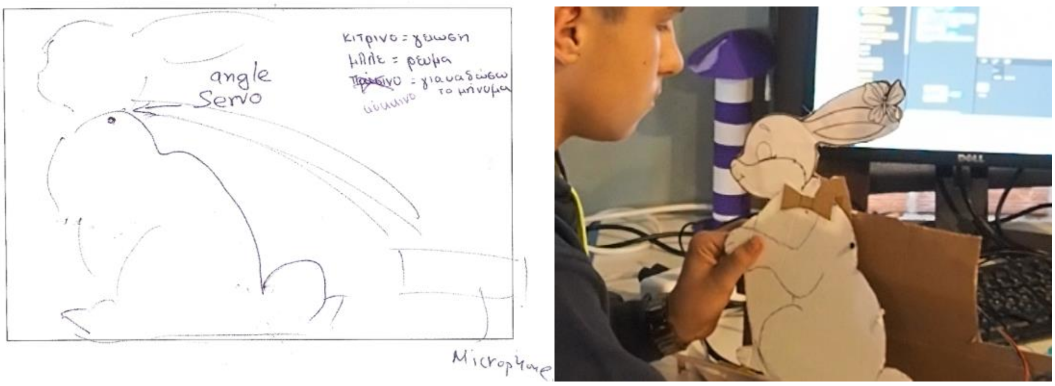


Figure 22: Student's drawing on paper as of the planning phase (left) and the created artefact (right)

The project offered also opportunities for discussion, which mainly revolved around technical issues (i.e. the power of the motor in the case of using heavy cardboard) or the way of representing the behaviour of the animal at loud sounds. Different implementations were made as indicated in the representative pictures below.

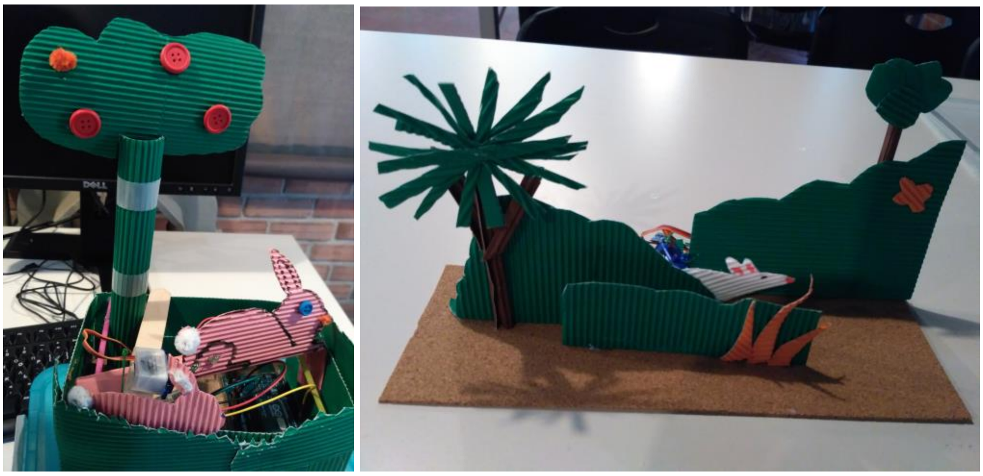


Figure 23: Two implementations for the Shy Rabbit project

Time allocated

Most of the groups completed the project within 3-4 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the structure and the rabbit
- wooden sticks
- wires and LEDs and breadboard
- small microphone equipped with preamplifier
- small angle servo
- Arduino Uno units

Technical details & software used

In terms of software, the students used either the Ardublock or the Snap4Arduino programming environment to program the behaviour of the rabbit. To program the rabbit so that to intercept a noise, students connected a microphone into the A0 input of the Arduino Unit and sketched a program that was polling values from this input. By observing the noise values that were being recorded, they defined a critical sound level value that corresponds to “tranquillity” and updated the code instructing an angle servo motor to “wipe” (i.e. to turn left and right several times) whenever sounds considerably louder than this threshold value where being captured. In order the servomotor to function properly, a PWM capable PIN was used that controlled the angle parameter.

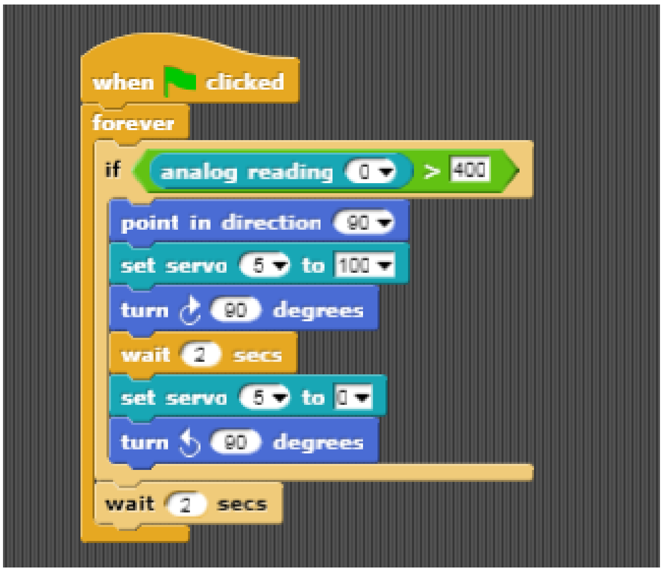


Figure 24: Indicative script for making the rabbit to intercept loud sounds

Video: https://youtu.be/TryERYW835w

4.4. The Sunflower Project

This project was implemented in the Greek formal and informal pilot site. The teachers introduced this project to the students as at that stage the generation of ideas from students’ side was not very mature. This project revolved around the phenomenon of phototropism, the orientation of plants according to the location of light. The students were encouraged to discuss this phenomenon in teams, and to search for information online about the phototropism in sunflowers. They were then encouraged to use the available eCraft2Learn tools, technologies and resources in order to simulate this phototropic response when the light stimulus is present.

The scenario of this project was selected by the teachers by the list of indicative scenarios that has been presented to them and discussed during the teacher training workshop (see D5.2). A worksheet was also given to the students to support their engagement in the eCraft2Learn process for this specific project *(available in the Educational Resources, in the Worksheets section in the Unified User Interface[5]).*

Some groups were noticed to make plans on the paper and to keep notes related to their project (see also section 2.2).

[5] Unified User Interface (UUI): https://ecraft2learn.github.io/uui/index.html#

Figure 25: Material list for the Sunflower project (in Greek)

Figure 26: Students' drawing: breaking down the problem in the main subtasks

This project was chosen due to two main reasons:

a) it introduces students into the parallel use of photoresistor sensors and angle servos, allowing the implementation of more complex functionalities from a STEM perspective. After becoming smoothly familiar with more complex combinations of the eCraft2Learn tools and technologies, it was considered more likely to pinpoint possible topics of interest and to take initiatives in working on their own project ideas.

b) it provides excellent opportunities for opening up discussion about the phenomenon of phototropism and environmental factors that might cause a plant to move or face a different direction. Thereby, it is ideally suited in the 'Flexible Zone' of the Greek school for cross-thematic activities.

Figure 27: Looking into the Sunflower design

Figure 28: Different designs under the same project topic

Time allocated

Most of the groups completed the project within 4-6 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the flower
- wooden sticks, metal wire, buttons, knitting kit
- photoresistors, resistors, wires, breadboards
- angle servo motors
- Arduino Uno units

Technical details & software used

The students used Snap4Arduino and Ardublock visual programming environments (available through the Unified User Interface), so as to program the behaviour of the flower. More specifically, they experimented with two light sensors (photoresistor based ones) and gave motion to a flower artefact so as this to turn towards the direction with the highest light reading. To achieve this, the light sensors outputs were directed to the A0 and A1 inputs of the Arduino Unit, respectively. The code on Arduino periodically polled these two values, compared them to each other instructing an angle servo motor to turn towards the direction that was exhibiting the strongest reading. The servomotor was connected to a PWM capable Arduino digital PIN.

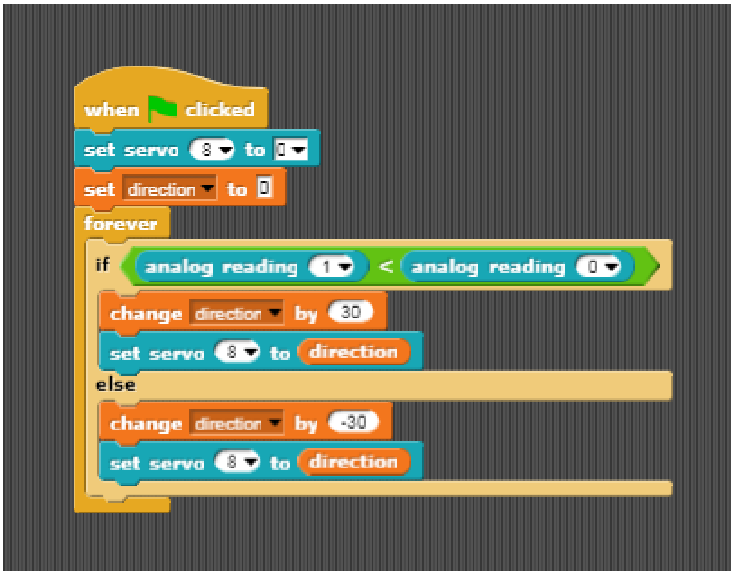


Figure 29: Indicative script for directing the Sunflower towards the light

Video: https://youtu.be/YfQa5e01zbc

4.5. The Christmas Artefacts

The idea for Christmas-related artefacts came from the students just before the Christmas period. The Christmas projects were implemented by some groups both in the formal and the informal pilot sites in Greece. The idea for this type of project had been discussed with the teachers who supported the students in ‘bringing into life’ their projects. Different projects were implemented that fall into the Christmas thematic topic: Different types of Christmas trees with blinking lights, Christmas boxes that reproduce tunes, Christmas figures (i.e. Rudolf) and more.

Among the ideas that were discussed was the ‘Christmas boat’ with lights. The decoration of the boat is a Greek old Christmas tradition. During the decades the Christmas boat was replaced with the Christmas tree. Students’ idea was to make a handmade paper and/or wooden boat of small size with lights in order to revive this old tradition. Although the students gave up this idea and implemented Christmas gift boxes that reproduce Christmas sounds, an interesting discussion was raised between teachers and students about this old tradition.

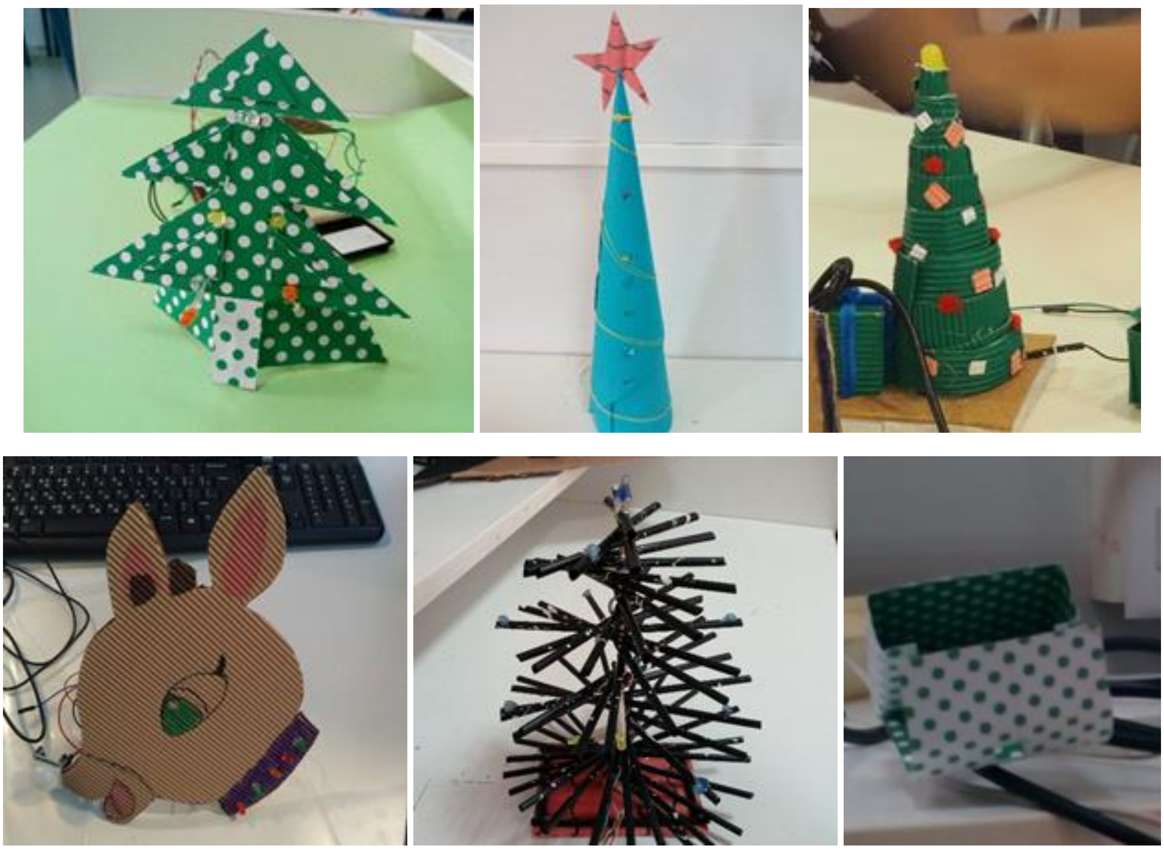


Figure 30: Examples of the Christmas artefacts that were created by the students

Time allocated

Most of the groups completed the project within 3-4 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the Christmas objects
- wooden sticks, plastic straws, metal wires, rope
- glue, duct tape
- PIR motion sensors, microphones
- LEDs, angle servos, speakers
- Arduino Uno units

Technical details & software used

Having acquired enough experience on how to use visual programming tools like Ardublock or Snap4Arduino and on how to connect simple sensor units or action elements on Arduino boards, the students were noticed to combine techniques for the needs of this project. The basic idea was to poll the sensors and trigger the relevant action, whenever an empirically defined threshold value was exceeded. PIR motion sensors as well as microphones were used to create triggering events. The new “player” (i.e. apart from light or moving actions) in that case was the invocation of sounds (i.e. beeps using the Arduino pins) or even of music (of moderate quality) via the Snap4Arduino environment running on the RPi3 units. In both cases small speaker units, equipped with amplifier, were used.

Video: https://youtu.be/QpJ8oxm4sxo

4.6. The DIY Automobiles Projects

The students’ diaries revealed the fact that many students expressed an interest in creating a car or a moving robotic artefact that can be controlled by them. In this light, the students encouraged to work on their robotic artefact with a focus on having it move around (left, right, forward, reverse) using servo motors. Some teams focused on adding wheels and connecting them to servo motors, programming the movement and addressing a specific behaviour, making the robot autonomous using a solar bank; some others started designing models useful for their robotic artefact.

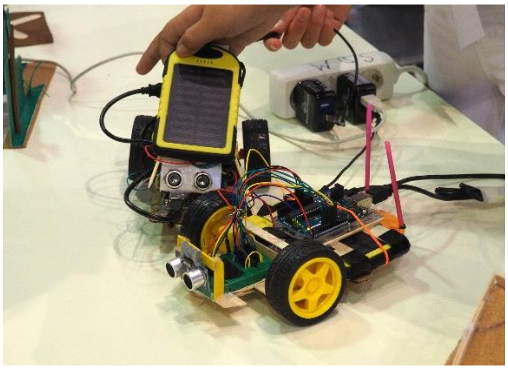
The engagement in the DIY automobiles projects offered opportunities for:

- exploring scientific and engineering principles behind building a solar-powered car
- exploring scientific and engineering principles related to motion and friction
- discussing the need for lightweight material and construction
- engaging into programming tasks
- engaging into electrical circuit making
- 3D modeling objects that will be needed (i.e. cases for solar banks, name tags etc)

Different types of DIY automobiles were created during the 2 pilot rounds that fall broadly into 4 main categories (see also video at: https://youtu.be/x6MKmQSq9CE):

1) Simple DIY automobiles

This category includes different automobiles either powered with solar banks or not. The automobiles could move forward and backward according to the programmable by the students’ behaviour.



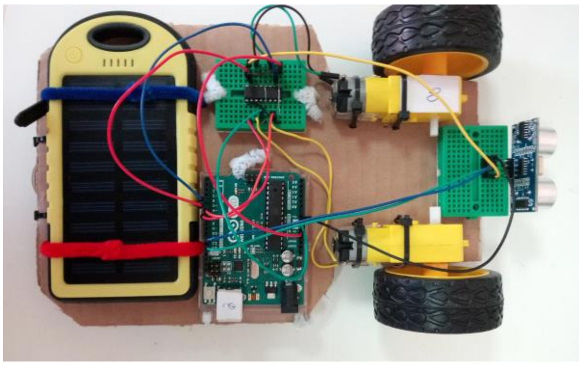


Figure 31: Students' projects

2) DIY automobiles that perform complex movements

Due to lightweight material and construction, smart choice of wheels the DIY automobiles of this category could perform complex movement, could turn left and right, freeze or move backwards when obstacles were ahead and more. Noteworthy, the address of this advance behaviour was premising a more advanced script. Led lights that were blinking according to the movement had been also attached.

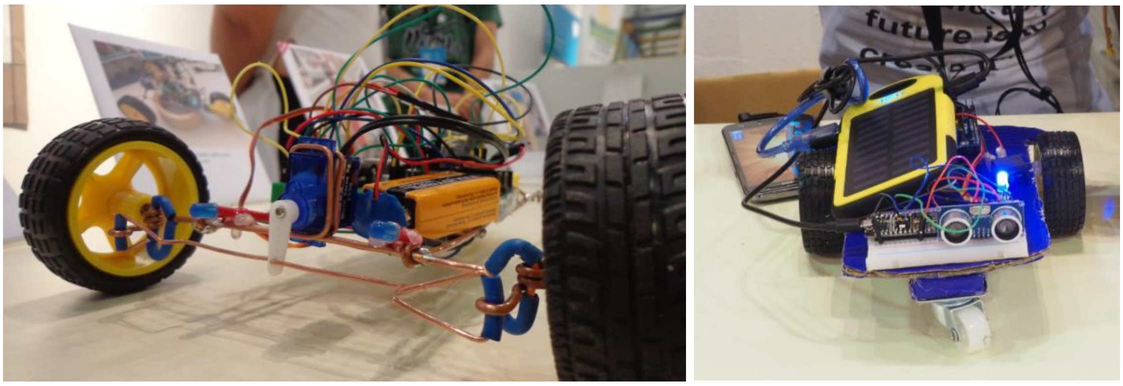


Figure 32: Advanced DIY automobiles

3) DIY automobiles decorated with 3D printed and sketched objects

This category includes automobiles that recognise obstacles, perform specific movements and in addition are decorated with 3D printed or 3D sketched objects.

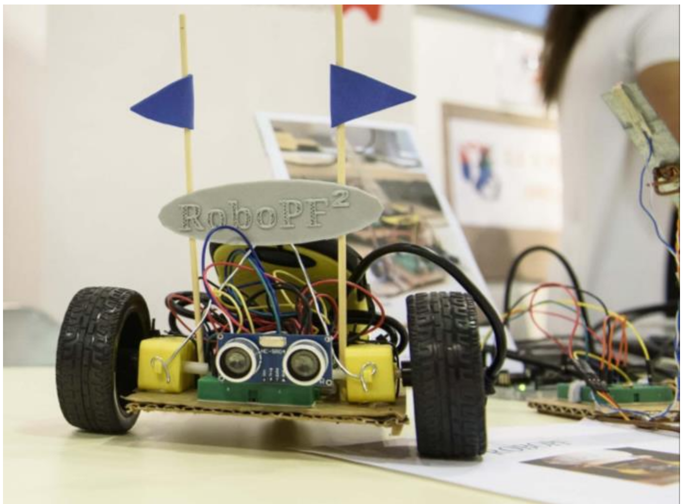


Figure 33: The RoboPF^2 automobile

4) DIY automobiles with remote control

During the 2nd pilot round in Athens (Greece) one team from the informal pilot site developed an interest in remotely controlling the DIY automobile using a tablet or a smartphone. Building upon previous designs, after many improvements and new implementations in order to achieve the remote control, the team successfully completed the project.

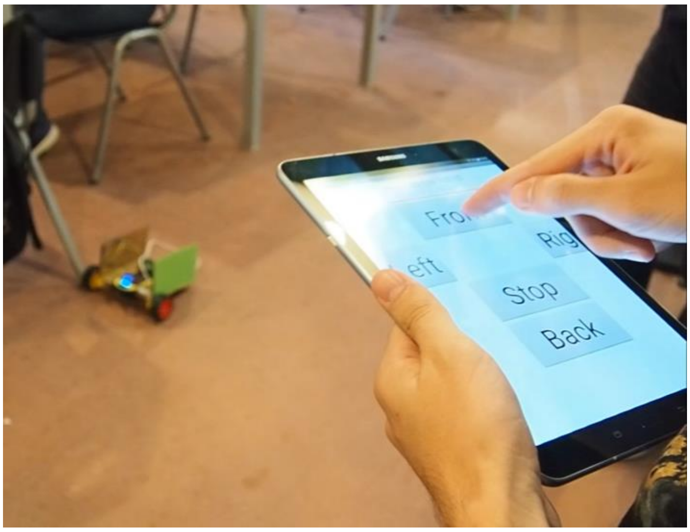


Figure 34: Remote control of the DIY automobile

Time allocated

The time that was dedicated in each project varied from group to group and from implementation to implementation. Simple DIY automobiles were made within 5 hours but more advanced functionalities and behaviours required more time and lots of testing and experimenting. The enhancement of the automobile with 3D printed objects (i.e. nametags, PLA cases) extended the implementation time as 3D printing itself was a time-consuming task. Thereby, depending on the complexity of the artefact 5 to 15 hours were spent.

Hardware and materials that were used

- cardboards, foam board, recycled material and many different types of paper for making the vehicle body
- wooden sticks, metal wire, straws to mount the axles
- wheels (plastic bottle caps, film canister caps, toy wheels)
- glue, duct tape
- jumper wires, LEDs, breadboards
- distance sensors (mainly ultrasonic ones)
- motor driver circuits like the L293D
- Arduino Uno units (for the simpler vehicle implementations)
- additional RPi3 units (instead of Arduinos) for the most composite remotely controlled implementations
- PLA filament for the 3D printed parts and 3D sketched parts
- 3D pen and 3D printer

Technical details & software used

As the issue of creating robotic vehicles had drawn a lot of attention, several types artefacts were created, varying from comparatively simple ones to autonomous and remotely controlled ones. The Unified User Interface (UUI) provided various tools for carrying out the following implementations:

- **Simple DIY automobiles**
  The simplest robotic vehicle implementations were able to move back and forth using USB cables or power banks to supply motors and Arduino Units. Programming took place either in Ardublock or Snap4Arduino.

- **DIY automobiles that perform complex movements**
  These computer-supported artefacts were able to calculate the distance from obstacles (via distance sensor readings) and avoid them (i.e. by going a few centimetres back and turning to the left or right before moving forward again). These were mainly Arduino supported artefacts. Programming took place either in Ardublock or Snap4Arduino.

- **DIY automobiles decorated with 3D printed and sketched objects**
  These computer-supported artefacts had been enriched with 3D printed parts. 3D modeling took place in Tinkercad and the slicing in Cura environment. 3D pens were also used in some cases for decorating the artefact. These artefacts were either Arduino or RPi3 supported artefacts.

- **DIY automobiles with remote control**
  These computer-supported artefacts, based on dedicated RPi3 units, instead of Arduinos, use the RPi3s' built in Wi-Fi unit to communicate with the Snap4Arduino environment (on the workstation units) or with a tablet device; the latter through the MIT App Inventor software (available through the UUI).

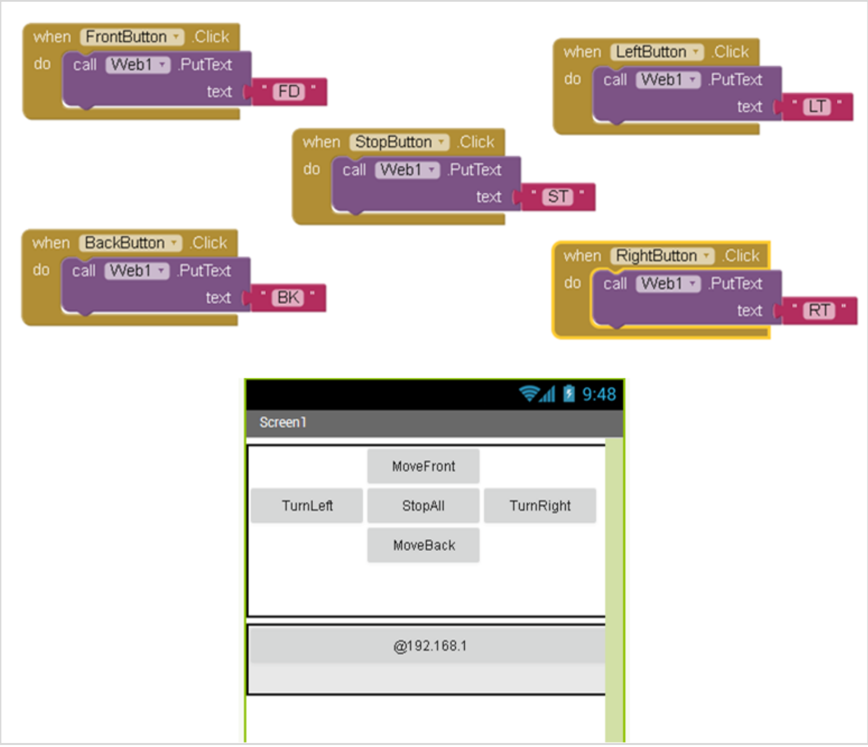


Figure 35: Indicative program code and interface design using MIT App Inventor to remotely control a RPi3 based automobile.

Video: https://youtu.be/x6MKmQSq9CE

4.7. The Solar Panel Project

As it has been mentioned above, the solar panel project emerged while a teacher was discussing technical details related to the Sunflower project (see section 4.4) with a group of students. Transferring the technical solution in a new context was considered as an excellent opportunity for challenging students' thinking. The group took up the challenge and guided by the teacher implemented the solar panel project. The outcome was a simulation of the behaviour of the solar panel in intense light. The solar panel artefact that was created was also seen as a didactic tool for introducing the concept of solar energy in additional school classes.

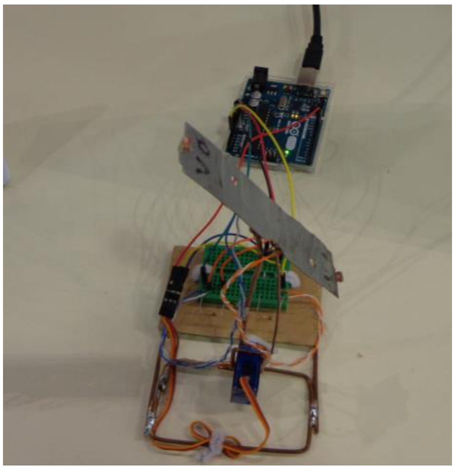


Figure 36: The solar panel artefact

Time allocated

The project was completed within 3-4 hours (given previous experience in the Sunflower project).

Hardware and materials that were used

- cardboards, metal piece and metal wires
- wooden sticks, metal wire
- photoresistors, resistors, jumper wires, breadboard
- angle servo motors
- Arduino Uno board

Technical details & software used

The methodology from a technical perspective, behind this project is identical to the one used in the Sunflower project. The only difference is that, instead of a flower, in this case, a metal piece (representing a solar panel) had to be directed towards the intense light. The students worked on Snap4Arduino visual programming environment to accomplish the project's objectives. As it happened in the Sunflower project, the light sensors outputs were directed to the A0 and A1 inputs of the Arduino unit, respectively. The code on Arduino periodically was polling these two values, comparing them and instructing an angle servo motor to turn towards the direction that was exhibiting the strongest reading.

Video: https://youtu.be/7GXiWrZ1cnc

4.8. The 3D Bridge Project

This project was implemented in the formal pilot site in Greece and was drawing upon another project that was on in the school by another class with 16-17 years old students. This class was studying the structures of different existing bridges (old historical buildings and modern ones) replicating the design using metal and different other materials. This practice inspired the eCraft2Learn group, which decided to model a bridge structure using 3D printing technology.

Figure 37: Examples of the bridges that inspired the 3D bridge project

The Visual Arts teacher, invited students to review famous bridge paintings that could potentially inspire their creation. Apparently, the students drifting from their classmates' designs approached the topic from a purely engineering perspective. Their interest was on designing a bridge that can hold a lot of weight. Supported by their teachers, 2 teams joined forces and reviewed different bridge structures. They decided to work on a space frame structure, the Warren Bridge structure[6]. Before entering into 3D modeling, they decided to represent the structure using wooden sticks and carry out experiments related to the weight that the structure can hold.

Figure 38: The wooden bridge and part of the 3D printed bridge as demonstrated in Athens Science Festival

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[6] More information about the Warren Bridge Structure can be found at https://www.garrettsbridges.com/design/warren-truss/

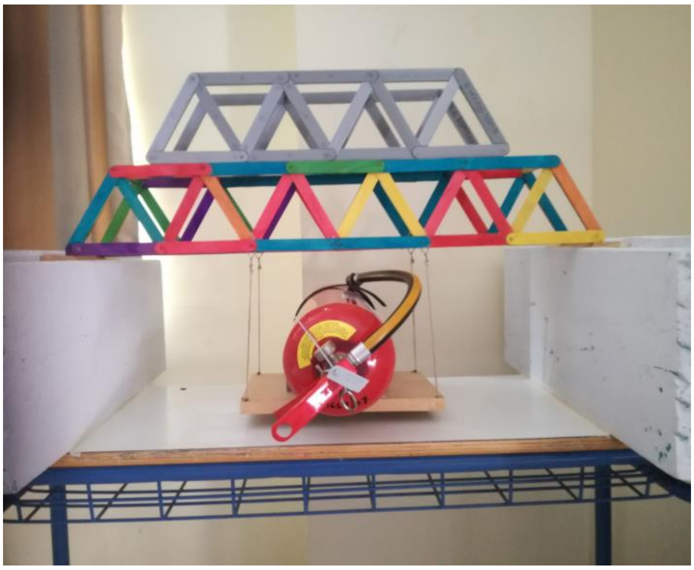
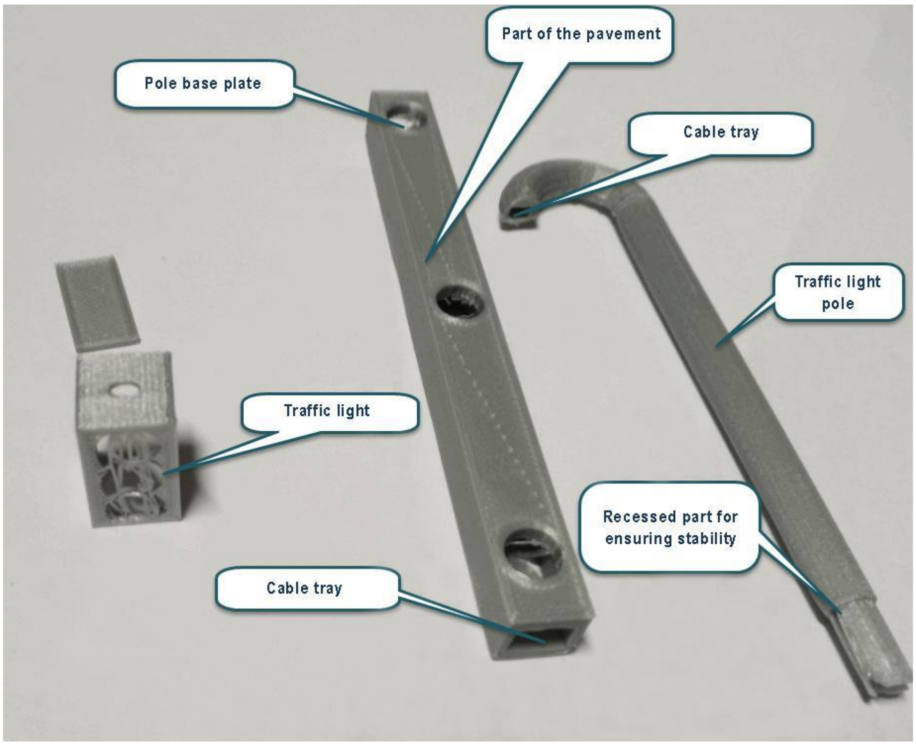


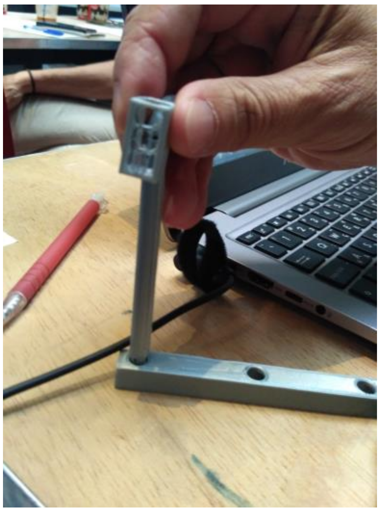
Figure 39: Additional tests of the bridge structure in the school environment

Once they decided upon the design, they 3D modelled the pieces of the bridge and activated the 3D printing process. This was a time-consuming task; to speed up, 3D printing carried on additionally after workshop hours under the supervision of the teachers. The first pieces were used to test the quality of the design and whether the assembly was possible. Once they test this, they continued with the 3D printing tasks to complete the entire structure.

After designing the structure of the bridge, the teams proceeded with the design of 3D printed components such as traffic lights, traffic lights polis, pole base plates and more. The idea was to prepare the structures that can be used for adding automation in the bridge later on: lights that turn on at dark and traffic signals that control the traffic in the bridge (switching between red and green).

Figure 40: The 3D printed bridge structure





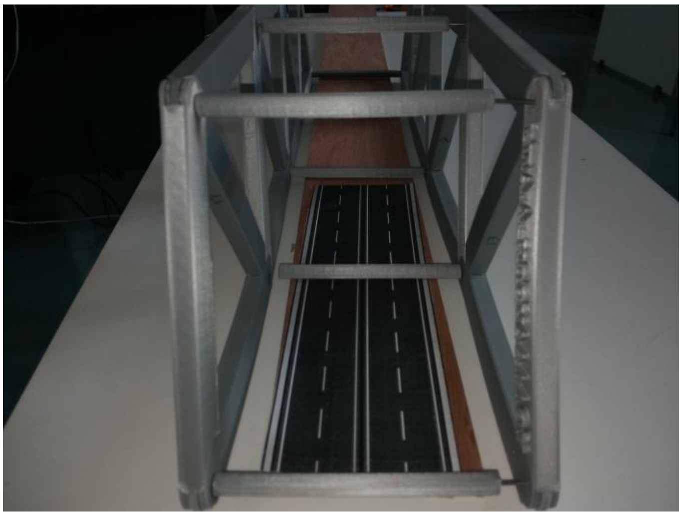


Figure 41: The 3D printed peripheral components and the bridge

Time allocated

- 15 hours were spent on this project by the students (including review phase, simulation, 3D modelling and part of the 3D printing tasks), additional time was spent by the teachers for the 3D printing needs
  - Each piece (from the bridge structure) needed 1-2 hours of printing
  - The traffic lights and peripheral components required an additional 3D printing time of 6 hours
  - 2 3D printers were used to reduce the 3D printing time

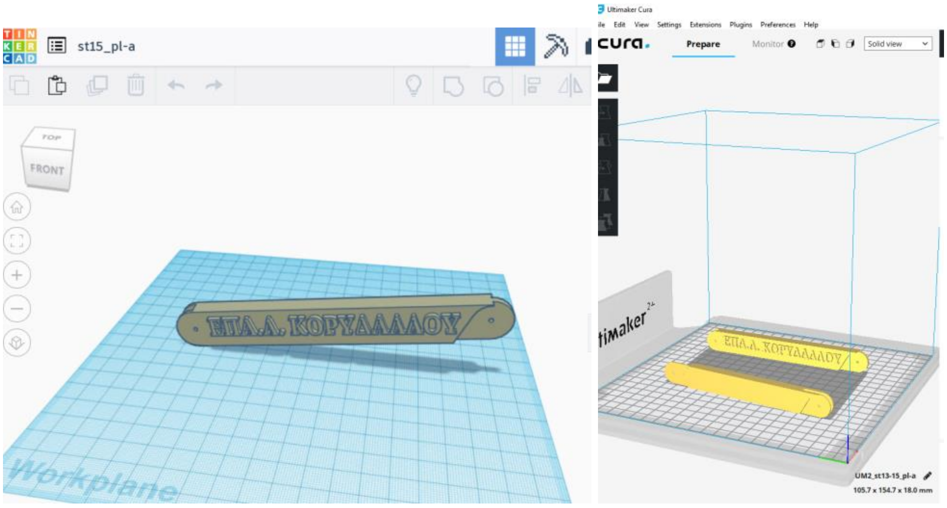
Hardware and materials that were used

- wooden sticks
- PLA filament

- silicon and silicon pistols or strong glue
- 3D printers
- Arduino Uno boards, wires, resistors and LEDs (for the automation)

Technical details & software used

The design of the parts of the bridge structure was carried out in Tinkercad, which is available through the UUI (Unified User Interface). The .stl file (that was produced in Tinkercad) was transferred to Cura where the slicing took place. The result of the slicing process was a g-code, the language that the printer understands and uses to create a 3D print. The g-code was transferred to the printers that were available in the eCraft2Learn lab.



The 3D model in Tinkercad (left) and in Cura (right)

The printing material was PLA and the nozzle size was set to 0.4mm. The speed was set to faster and the infill was set to 18%. The option for build plate adhesion was selected.

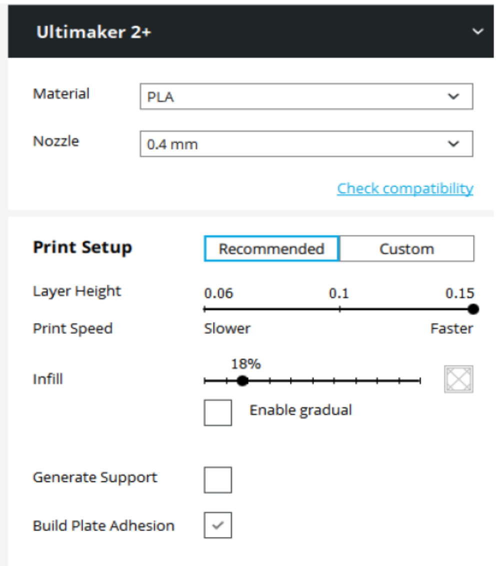


Figure 42: Setting in Cure for the 3D printed parts of the bridge structure

The electrical circuits were simulated and tested through the Tinkercad Circuit Design (available through the UUI)

4.9. The Joypad for Controlling a Video Game

This project was drawing upon a students' previous attempt to create a simple video game in Scratch (the attempt was made after the 1st pilot). The student presented the game in his team members explaining that some improvements are needed. The team members got excited with the video game and started considering possible advancements, among which the creation of a joypad for controlling the video game. Although the team reviewed several ideas for implementation (not necessarily relevant to the video game), in the end took up the challenge to create a video game joypad. This was a real challenge for them as it required design by scratch bridging the physical and the digital world. The students all together documented several ideas and listed the materials that would be needed. The joypad was designed as a box with buttons that can be pressed (see Figure 43).

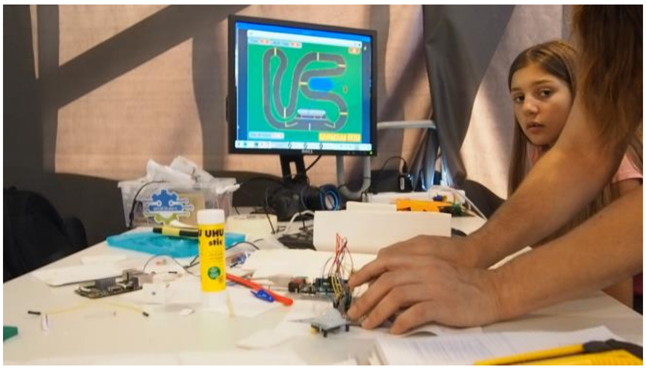
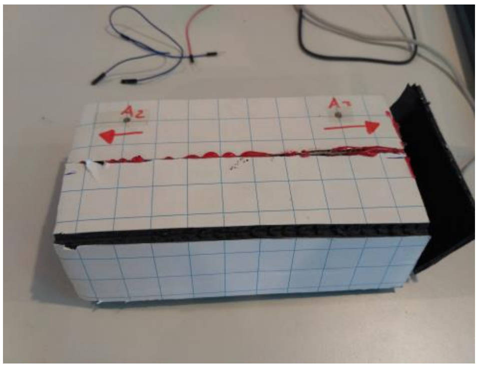



Figure 43: Controlling the avatar using the main mechanism (left) and the final joypad box (right)

The team soon realised that the design should be tested by possible video game users so that to come up with a design that meets their needs. This interesting observation by the students was an encouraging sign that they start recognizing the need to see design through the lens of someone else, going deeper into design thinking practices and real-world approaches.

Time allocated

The basic design of the functional joypad was completed within 16 hours.

Hardware and materials that were used

- cardboards for making the joypad box with the buttons
- wooden sticks for supporting the box, glue, duct tape
- jumper wires, breadboard, touch sensors
- Arduino Uno board

Technical details & software used

The project has been implemented using MIT Scratch but several trials made using the Snap4Arduino environment as well. The students used sensors to intercept finger touch so as to direct the virtual figure in the scene to the left or to the right.

Video: https://youtu.be/QZHyYlv87no

4.10. THE 3 LEVEL SECURITY CONTROL SYSTEM

This project was implemented during the 2nd pilot round in the informal pilot site in Greece. The idea for this project came directly by the students. Their idea was to construct a progressive warning alarm. The alarm offers 3-levels of control and the students envisioned it as a mechanism that can fit in many different contexts. At the first level, the mechanism detects the movement of a suspicious person and turns on a yellow light. As the person moves ahead, a second alarm is activated; a light turns red and an alarming sound is heard. Then a third level of control is activated and the door closes and reopens only when no movement is detected. The project uses the readings from an ultrasonic distance sensor to activate the relevant alarm zone.

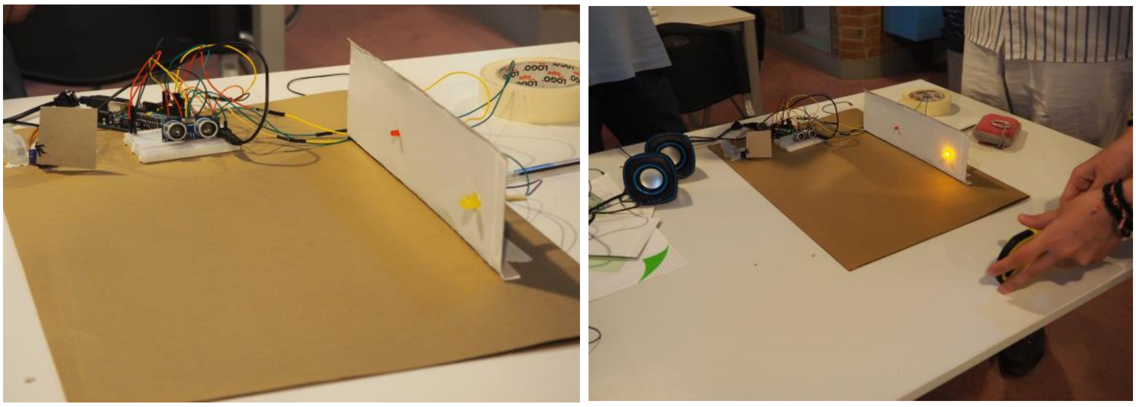


Figure 44: Testing the 3 levels of the security control system

Time allocated

The group completed the project within 15 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the scenery
- glue, duct tape, wooden sticks
- jumper wires, breadboard
- ultrasonic distance sensor, LEDs, angle servomotor, speakers
- Arduino Uno units

Technical details & software used

The readings provided by an ultrasonic distance sensor are continuously compared to a set of different threshold values. The outcome of this comparison resulted in different alarm events to be triggered: blinking of the orange light, blinking of the red light, buzzing the speakers and closing the door attached on the servo’s axle. Although experiments had been made with Snap4Arduino, most of the work was carried out using the Ardublock programming environment, available through the UUI, as ultrasonic distance sensors work better there.

Video: https://youtu.be/kIENH2QB8as

4.11. THE VOICE DRIVEN FACE

In the context of this project, three groups of students carried out experiments related with the AI (Artificial Intelligence) capabilities of the UUI (Unified User Interface) platform, provided via the Snap! and the Snap4Arduino tools. The task was simple: to make a virtual face to move to the left or to the right or to stop, according to the voice commands given. After that, they performed experiments involving actual (Arduino controlled) commands to make a LED to alter its state properly or a servo motor to rotate.

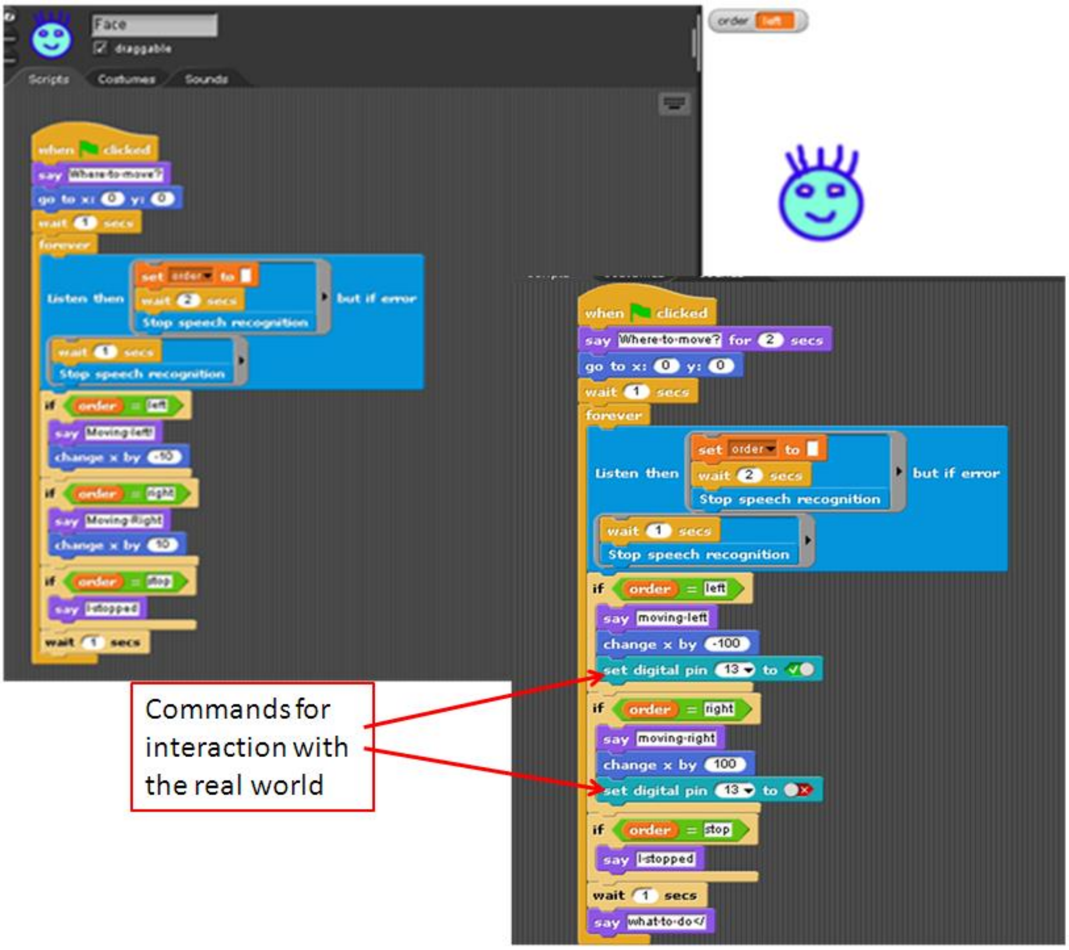


Figure 45: Program code for the Voice Driven Face project

Time allocated

Most of the groups completed the project within 5-6 hours.

Hardware and materials that were used

- For the pure virtual implementation: Just a USB microphone (actually the one built in a web camera) attached in the RPi3 workstation unit
- For implementations involving action elements, typical material and equipment may be used, as in the rest of the projects: cardboard paper, glue, breadboards, jumper wires, servomotors, LEDs.

Technical details & software used

In order to make the face to move to the left or to the right, the speech data, as provided via the USB microphone, were sent to the speech analysis engine connected to the Snap! (or to the Snap4Arduino) environment. The results of this analysis (i.e. the alphanumeric strings that matched with the commands being spoken) compared with predefined strings (i.e. “left”, “right”, “stop”) and the proper actions were programmed, for virtual or real-world scenarios, using Snap! or Snap4Arduino, correspondingly, via the UUI. The overall process was really challenging but CPU and network bandwidth demanding, as well. These conditions sometimes made the AI system to require more than one trials to respond properly and resulted in partial implementation of this project by some teams. The need for a faster than the RPi3 board was somehow apparent in that case.

4.12. THE PHOTOSYNTHESIS PROJECT

Photosynthesis was chosen as a topic for two student classes, for class one in Pataluoto school (photosynthesis project 1) and for class four in Lyseo school (photosynthesis project 2) as it was included in the Finnish national curriculum under the biology subject and a biology teacher was taking part in both projects. Students were already familiar with this phenomenon as introduced in earlier school grades but revised during the secondary school grades. Students could apply their previous knowledge into the eCraft2Learn projects.

Teachers proposed a task for students to create a representation of photosynthesis by using electronic components (Arduino with different sensors and actuators), 3D printing and crafts materials. The emphasis was on the reactants (light, water and CO2) in the photosynthesis process. Students used water sensors and photoresistors to observe and model the amount of water and light in the environment. For example, when there was enough water and light, an LED turned on to demonstrate that photosynthesis process was active. Or, when there was not enough water that the water sensor was constantly measuring, the plant watering system activated and a servo motor could let some amount of water to go through the pipe and increase the water level in the soil. CO2 was modelled with a slider when moving the slider to one end increased the (notional) amount of CO2 and other way decreased it.

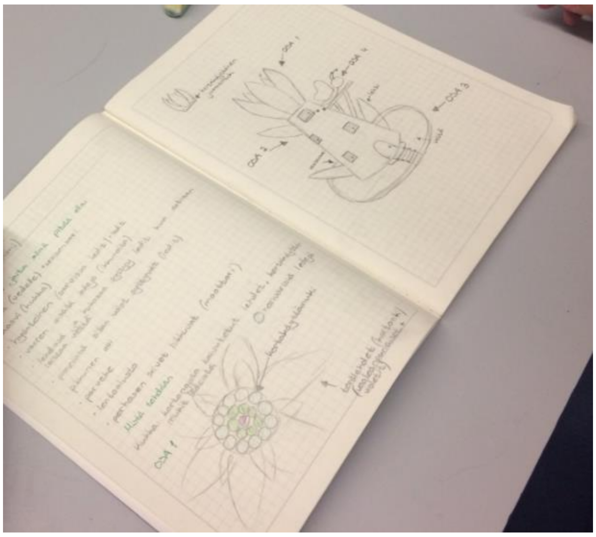


Figure 46: The photosynthesis representation made by one team: the flower house

This project combined biology and chemistry subject matters through phenomenological and inquiry-based work. It also fostered students' problem solving skills as well as their skills in arts and crafts subjects. In the first photosynthesis project, students produced representations of flowers from different materials (cardboard, playdough and 3D prints). The second project led to bigger variety of artefacts as student planned and created a greenhouse, a globe, a flower house and a self-watering system as photosynthesis representations. The difference that helped students to think more outside of the box in the second photosynthesis project was presumably the different way of teachers' when they oriented and instructed students in their ideation processes. When starting the first photosynthesis projects, teachers gave students an idea of a flower, hence all projects resulted to flower representations. In the second project, teachers were encouraging students to think for example where photosynthesis happens and who are involved in photosynthesis at any point of the process.

In the second class that carried out the photosynthesis project, the student groups were smaller (2-3 students per team) than in the first class (4-5 students per team), due to the size of the class. It could be noticed that the work in smaller teams was more effective and students were more on-task than in the teams that had more students. If there are teams with more students, it is good for the teacher to support and remind students to plan the task assignment and management carefully, as to maintain and promote the interaction among team members.

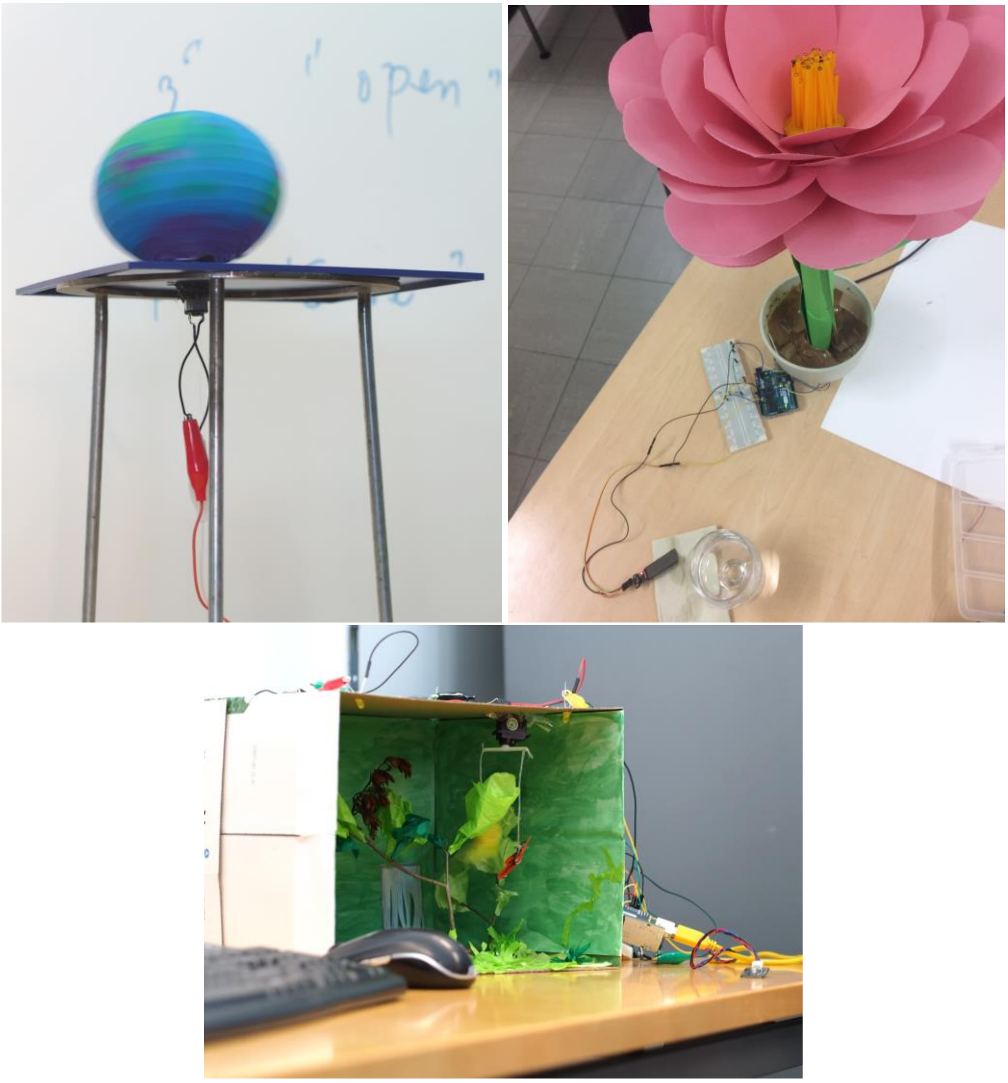


Figure 47: Examples of students' final artefacts: a 3D printed globe, a flower and a greenhouse

Time allocated

In the first class, groups completed the project within 7 school hours and in the second within 14 school hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the flower

- wooden sticks, plastic straws, playdough, yarn, paint, glue, tape
- real plant and soil
- Arduino Uno boards, wires, LEDs, photoresistors, water sensors, sliders, servo and DC motors
- 3D modelled and printed parts, PLA filament

Technical details & software used

In the photosynthesis projects, students did not use the UUI as it did not provide much functionalities at the time of the project implementation. Students opened Snap4Arduino from the RPi3 desktops and searched information through the internet browser. For 3D modelling students used Tinkercad from their own iPads or school laptops as RPi3s could not run the software adequately. However, slowness issues were identified with some of the iPads as well, but Tinkercad could be used with them and some students even preferred iPads over laptops.

In the first class, the teachers' idea was to create a simple representation of the photosynthesis process and its components (e.g., CO_2, water and light). In the second class, the teachers' idea was to create a representation of the climate change indicators, in other words the greenhouse gases. They wanted to create a "water vapour and carbon dioxide in a bottle" representation. It was noticed that the infrared sensors were not accurate enough for this purpose and the idea could not work in a way teachers wanted. That is why the original plan had to be changed and simplified into a photosynthesis project.

When building the electronic circuits, students were using analog pins from the Arduinos for all sensors and actuators in their creations (water sensors, photoresistors and sliders). As students wanted to make LEDs to turn on when there was enough water, light or CO2, they learnt to read analog values and use conditional statements. One student group created a globe and used a DC motor to make it spin. The wirings for a DC motor were relatively complex with the usage of an H-bridge and had to be provided by the teachers and project researchers. Though, students were introduced to the ready-made wirings and students learnt how to program the DC motor.

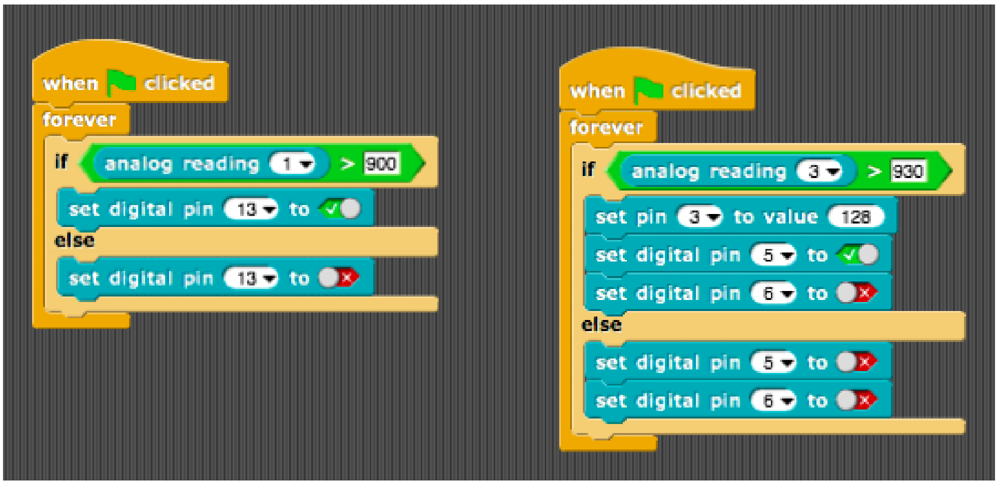


Figure 48: Screenshots from Snap4Arduino. *A conditional statement for any analog sensor used in the projects to turn on and off the LED (left) the program code to turn on and off a DC motor with analog sensor readings (right).*

4.13. The Security in Society Project

The security project was introduced by a social sciences teacher who was exploring the students' textbook that he uses to guide the teaching of different topics. He found security as one bigger theme of the book and was curious to try to bring it to students as an eCraft2Learn project.

In this project students became familiar with existing security systems in the society by exploring how security is maintained for example in museums, banks, shops and houses. One student team even looked into how security was managed in old castles and got inspiration from security during old times. Students designed a precious item to be protected from being stolen and created their own security systems around the item by combining crafts materials with electronic components and 3D printed parts. Students used touch sensors and distance sensors in windows and doors to detect movement, buttons to detect weight changes, servo motors to lift vaults or lower doors and LEDs and piezoelectric sensors to send the alarm with lights and sound.

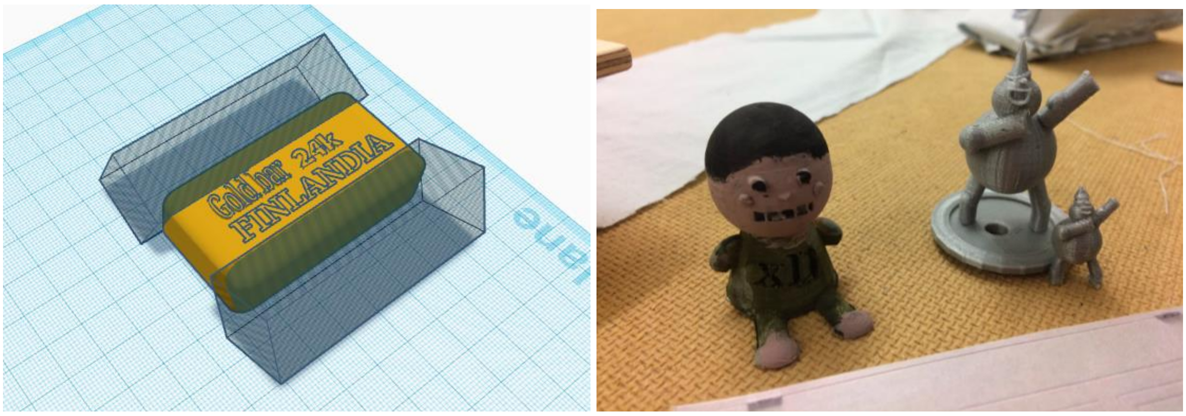


Figure 49: 3D models and prints as items prevented from being stolen

Students put a lot of effort in making detailed artefacts and used different skills from multiple subject areas such as wood, metal and soft crafts as well as arts, mathematics and history when creating their projects. As a part of the sharing, student teams were writing blog posts, filming short videos and making a catalogue with short learning diary type of texts.

Figure 50: Examples of student projects: security systems for a museum (distance sensor and button with LEDs) (left) and for a castle (distance sensor, button and servo motor) (right)

Time allocated

Most of the groups completed the project within 18-20 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the flower
- wooden sticks, wood, stones, metal, yarn, fabric, Styrofoam, paint, hot glue
- Arduino Uno boards, wires, LEDs, ultrasound and touch sensors, buttons, servo motors, piezoelectric sensors
- 3D modelled and printed parts, PLA filament

Technical details & software used

As the UUI did not provide enough functionalities at the time of the project implementation, students did not use the UUI tools. Instead, students launched Snap4Arduino from the RPi3 desktop. For 3D modelling students used their own iPads which were powerful enough to run the Tinkercad software in most of the times.

Student teams used a big variety of sensors and actuators in their projects, such as force sensors, distance sensors, button modules, LEDs, piezoelectric sensors, touch sensors and servo motors. Some of the used actuators were wired to the digital side and some to the analog side. With piezoelectric sensor and servo motors students learnt how to use the PWM pins in the Arduino. It was noticed that when combining multiple sensors together, the sensors' reading values were not anymore consistent. This issue where the Arduino could not provide enough power for all sensors to function appropriately was partially solved with adding a 0.05 second delay in the program code.

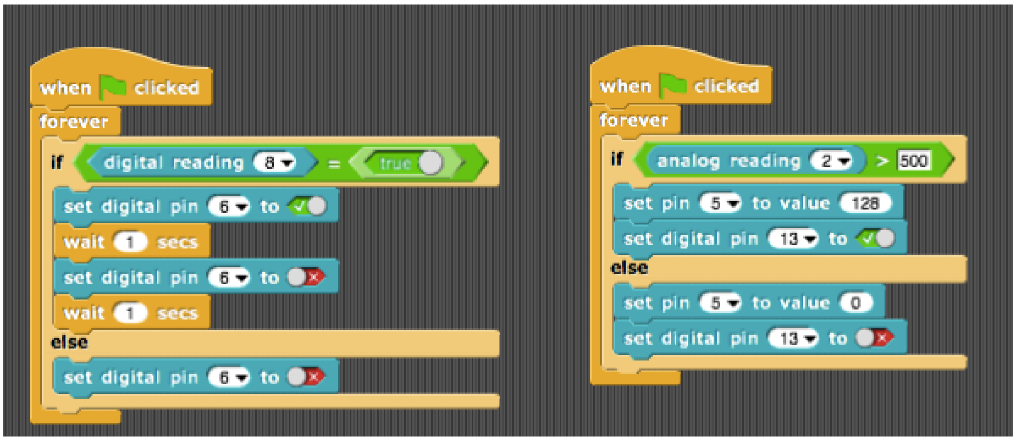


Figure 51: Screenshots from Snap4Arduino. The conditional statement for a button module used in the projects to detect if an item is removed and making an LED to blink (left). The conditional statement to create sound with piezoelectric sensor with analog sensor readings (right) (for example when someone walks into a room and distance sensor detects this movement).

Video: https://youtu.be/jOJjnYIVjwY

4.14. THE ROBOT HEAD

In the 1st round of informal pilot site, students had a task to create a robot that will move its head when someone is approaching it or when it notices too much light. The concept of a robot was very open and the projects could have animals, persons, fantasy characters or anything that corresponded to students' visions. As students in this informal pilot site were already experienced with electronics and programming, they had ambitious plans of robots that are shooting marshmallows for instance. All student teams could start their artefact creations after the topic was introduced and very little initial circuit building or programming practice was needed before the actual work.

All student teams got engaged in the 3D modelling and created parts for their robots with Tinkercad 3D modelling software. However, students did not plan how to attach sensors or actuators to their creations which resulted the 3D printed parts being difficult to use. In addition, although the students were creating their models with enthusiasm, not all models were 3D print friendly and it resulted some of the 3D prints failing in the printing process. Students would have needed more guidance on how to design the 3D models so that they are printable and suitable for their projects. Though, the failed 3D printed parts worked as a great start for discussion with the students on this topic.

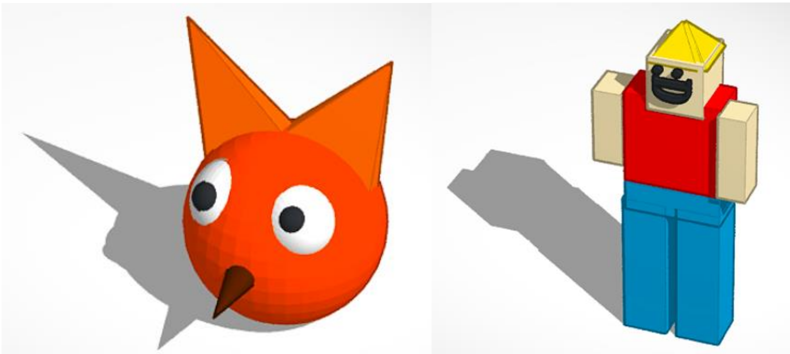


Figure 52: Students' 3D models for the robots

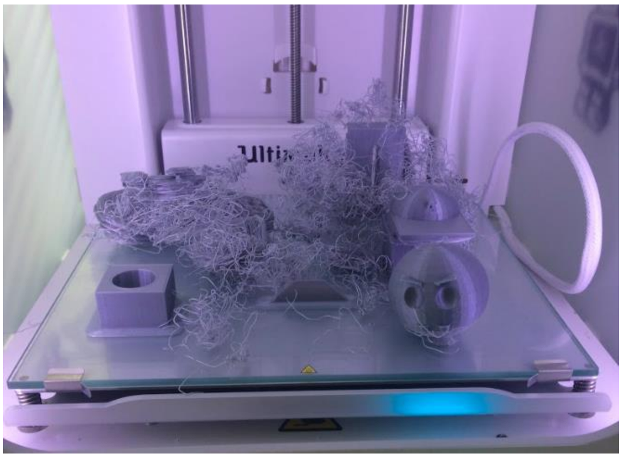


Figure 53: Unsuccessful 3D printing attempt

Finally, as there was no time for new 3D prints, students had to come back to their ideation and planning stages and create new plans. This was a great exercise for students to recover after failure and boost their problem-solving skills. Students created their artefacts from recycled materials and combined some of the 3D printed parts in the creations.

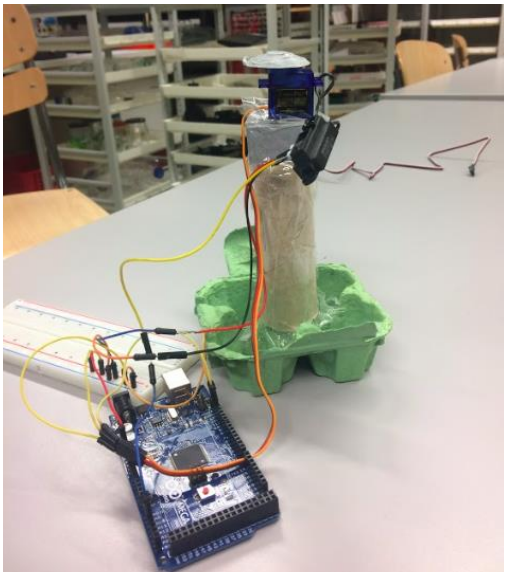


Figure 54: Example of a students team representation of a robotic head - a tower that detects movement and turns the top part according to it

Time allocated

Most of the groups completed the project within 8 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the robot heads
- Arduino Uno boards, wires, LEDs, distance sensors, servo motors
- 3D modelled and printed robot parts, PLA filament
- artificial intelligence speech recognition blocks in Snap4Arduino

Technical details & software used

Students logged in to the UUI in the beginning of each session with their team's name. Plenty of the UUI tools were used in different phases of the project, such as eCraft Search, eCraft Plan, Tinkercad 3D Design, Tinkercad Circuit Design and Snap4Arduino. The student teams used photoresistors, LEDs, distance sensors, touch sensors, servo motors and piezoelectric sensors in their projects. Few teams were also testing and using the AI blocks speech recognition with success. During the pilot sessions, the informal pilot site educators were testing the eCraft2Learn learning analytics and for example observing which search words students were using and how many search results had generated.

One major issue was faced when using Snap4Arduino through the UUI on the informal pilot site laptops. The laptops had the Windows 7 operating system that required admin login for downloading anything on the laptops. Therefore, the Chrome plugins could not be downloaded and the Arduinos could not connect with the Snap4Arduino. This was fixed by using some additional laptops that had the Windows 10 operating system or Macbooks running MacOS.

4.15. The Cold War Project

In the Finnish curriculum, history subject should introduce students to some of the biggest Wars in history such as the Cold War, which was being studied during this eCraft2Learn task. A history and social sciences teacher presented the topic and students could find and focus on some specific event of the Cold War. This led to projects about the Cuban Missile Crisis, the Berlin wall, the Korean War and one project about a bomb shelter. During the projects, students could also consider the human rights issues during the Cold War.

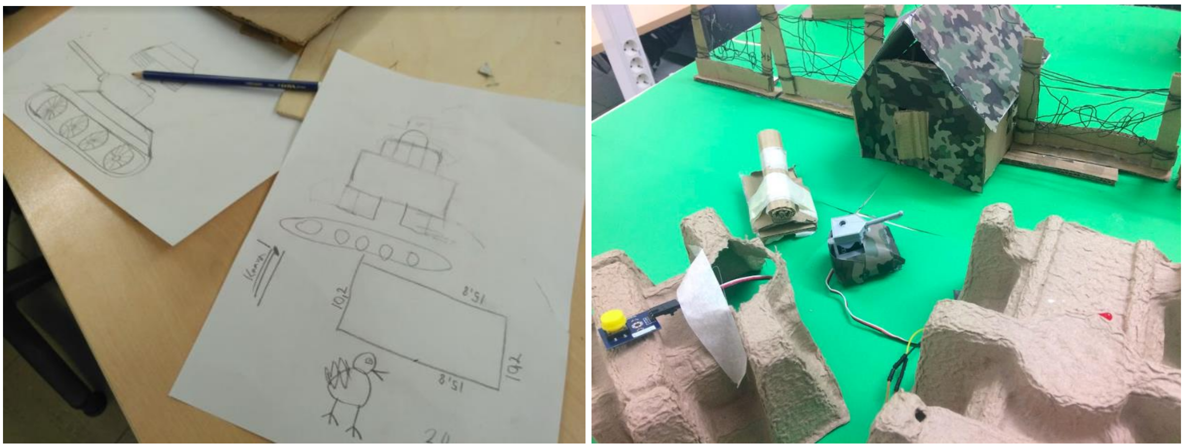


Figure 55: Sketch for the tank (ideation and planning stages) that was featured in the Korean War project.

This teacher had already implemented two projects about the security in society (see 4.13) in the 1st pilot round and he had noticed that one 45-minute class was too short time for one session in a project-based work like experienced in eCraft2Learn projects. Therefore, he arranged the lessons for this specific student class so that he could have four complete days of four hour each dedicated only for the project work. Having longer sessions brought the feeling of continuity to the working and students could achieve a lot during one session. However, four hours started being the upper limit for the work which students had concentration and motivation, although they could have their own breaks whenever they felt it necessary.

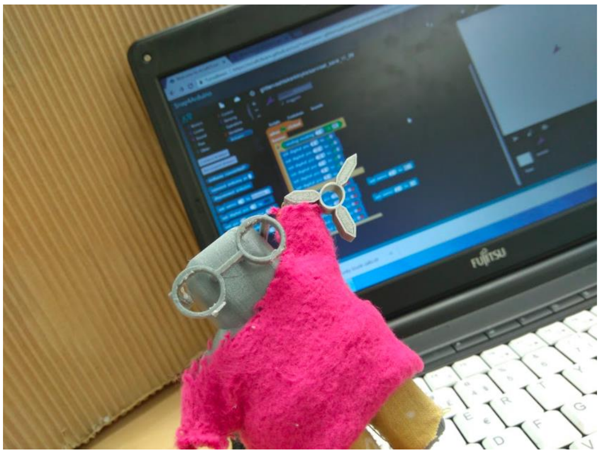


Figure 56: 3D modelled and printed character and initial program code for one student project

During the projects, the students faced multiple practical engineering issues when they had an idea and tried to find out a solution how to make the idea work. Teacher's support was needed and he was actively fostering this problem-solving process. For example, in the bomb shelter project students were thinking how the latch of the door should be done to open and close the door. Students then investigated different solutions, such as the train wheel movement to understand how to make straight movement out of a round movement, to find a solution for how to create the latch to make the door work properly.

Figure 57: Examples of students' projects: the Berlin wall and watchtower with distance sensor and turning LED light (left) and the Cuban missile crisis representation (right)

Time allocated

Most of the groups completed the project within 13-14 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the creations
- wooden sticks, wood, natural materials, stones, metal, fabric, paint, hot glue
- Arduino Uno boards, wires, LEDs, ultrasound sensors, buttons, servo motors
- 3D modelled and printed parts, PLA filament

Technical details & software used

Students used the UUI extensively, starting from the ideation with the eCraft Search tool (finding videos and pictures), creating 3D models and electronic circuit simulations with Tinkercad 3D Design as well as Tinkercad Circuit Design and programming with Snap4Arduino. For the 3D prints, one student team used the Tinkercad 3D Design software to find ready-made 3D models and Cura was used as the slicing software.

Mostly, the student creations required the use of analog and digital sensors, servo motors with Arduino PWM pins and LEDs. The visual programming environment was chosen as it provided an approachable way to program for students that did not have much earlier experience on programming.

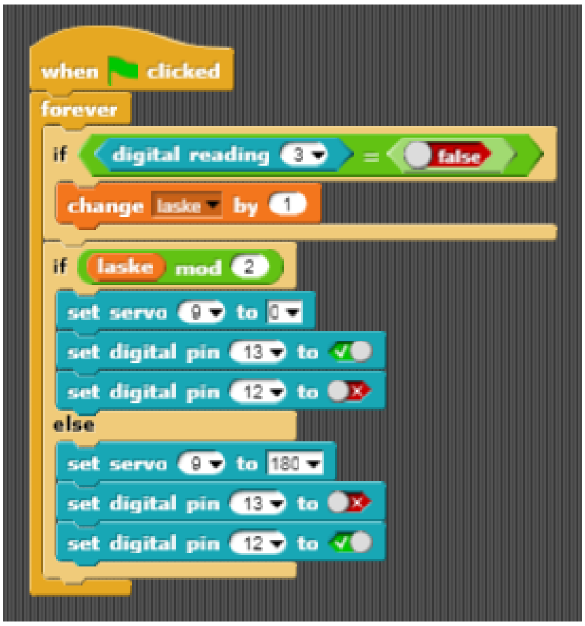


Figure 58: Program code for a button to turn a servo motor with every click. This code was used with a tank to turn the turret in the Korean War project.

Video: https://youtu.be/m8y3tI60XuQ

4.16. The Solar System

A physics and a biology teacher decided to carry out a project together with 14-year-old students that had already participated in the 1st pilot round in formal context. A solar system was proposed for students as it its included in the Finnish curriculum and teachers thought it could be inspiring for students to develop great projects. First, students started looking into the topic by getting to know the structure of space and solar system. Students narrowed down the topic and chose a small part that they could create a representation.

Figure 59: A plan and the physical artefact of planets in the Solar system, planets are orbiting with servo motors

One student team created a model of all planets with crafts materials and got the planets to orbit with servo motors. Another team drew all planets on a cardboard and attached LED lights to each planet. They then used simple voice commands and artificial intelligence (AI) programming to light up these LEDs according to the spoken word. Many electronic components and circuits (Arduino) with 3D modelling and AI programming were used in these projects. The student projects integrated multiple subjects as students used their competences and skills flexibly to implement their plans into action. Students were for example calculating the correct planetary sizes and distances with their mathematical skills.

Students presented their work in the SciFest 2018 science festival in Joensuu for national and international visitors including children, parents and teachers. This was a valuable experience for students to explain their work, enhance their understanding of the electronics and programming and get feedback.

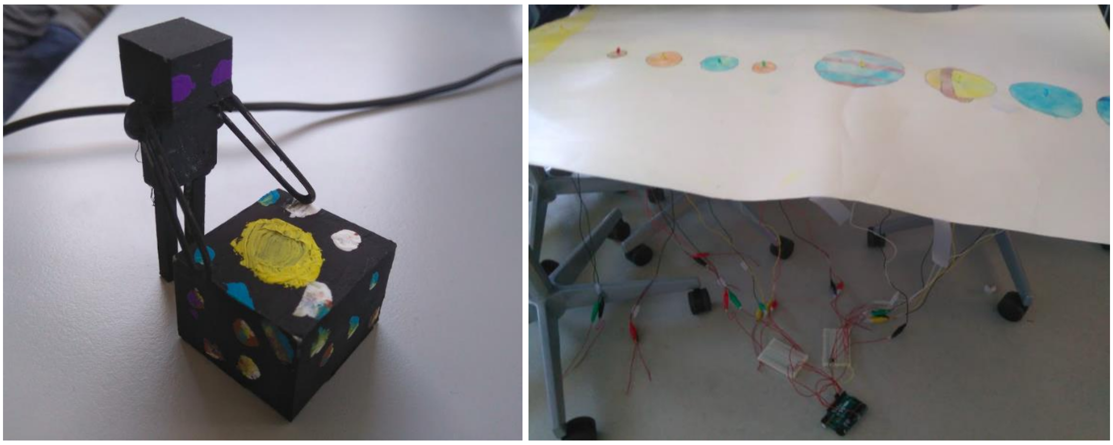


Figure 60: Examples of students' projects: a character that gives information about the Solar system (left), and a representation of the planets (when saying a planet's name, a corresponding LED lights up) (right)

Time allocated

Most of the groups completed the project within 9 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the creations
- Styrofoam, metal, paint, hot glue
- Arduino Uno boards, wires, LEDs, servo motors
- 3D modelled and printed planets and other parts, PLA filament
- artificial intelligence speech recognition blocks in Snap4Arduino

Technical details & software used

The UUI was in extensive use during the 2nd pilot round. Teachers provided students few files to help the planning stage through the Teacher uploads. Students were searching ideas from the eCraft Search and from Thingiverse, drawing sketches with the eCraft Plan, making 3D models with Tinkercad 3D Design and programming with Snap4Arduino. Moreover, the AI speech recognition blocks were imported to Snap4Arduino and used in multiple student projects. Teachers introduced these AI blocks to students first by providing a ready made code which students interpreting and later students could create their own codes with the available blocks.

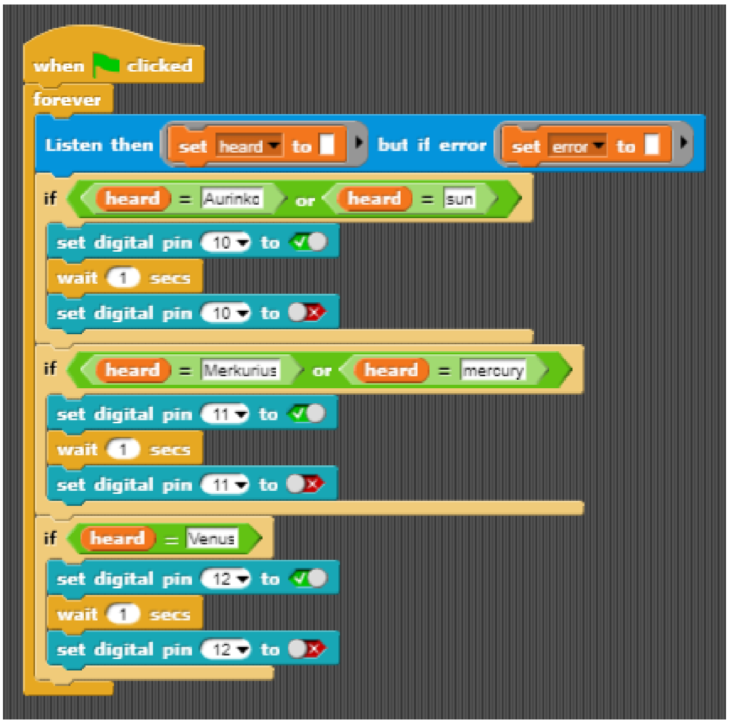


Figure 61: An example of a program code where the AI speech recognition blocks are being used. Specific words lights up a corresponding LED to demonstrate the planet

4.17. Geographical Phenomenon project

This project was implemented in a geography classroom and teacher's idea was to set a very wide topic where students could represent any geographical phenomenon. Students experienced the ideation process challenging which led the teacher providing some possible project ideas, such as a map that could present for example the world, Finland, some cities or volcanoes. The teacher also introduced AI programming for students. All student teams chose the suggested idea of making an interactive map where a flat map was enhanced with geographical information by using the AI speech recognition blocks. One student team created a map of South America, one of Finland and two teams of Europe all with different information. To add a touch of humour, the team with South America map used bananas as their sensors to show information on the map. Usage of fruits as sensors was possible as fruits are conducting electricity and closed electric circuits could be created.

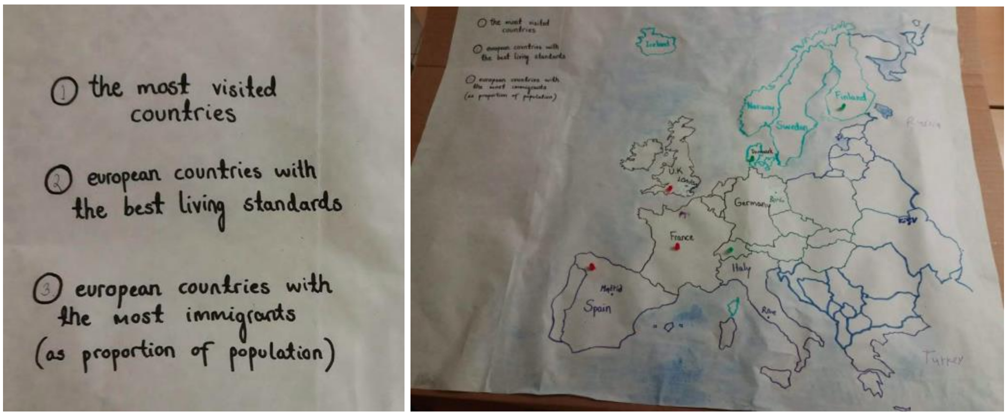


Figure 62: Information that students provided on the map. Using AI speech recognition blocks, asking a specific question lights up the correct LED

Students had previously studied maps, thus this project functioned as revision where students could apply and deepen the knowledge they had acquired during the earlier geography lessons. Students were searching information on the chosen topic to provide accurate info with their maps. During the artefact creation, the teams that chose to print their map progressed much faster and more effectively than the teams that decided to draw their map from the scratch.

Figure 63: Examples of student projects: LEDs to indicate relevant information on the map when a specific word or question is told or a sensor (banana) is touched

Time allocated

Most of the groups completed the project within 7-8 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the maps
- Arduino Uno boards, wires, LEDs
- fruits
- artificial intelligence speech recognition blocks in Snap4Arduino

Technical details & software used

Students used mainly the Snap4Arduino programming environment and integrated the AI blocks in their artefacts for making the maps interactive. One problem with the school laptops was experienced when using the AI speech recognition. The internal microphones did not function in the laptops so external microphones and headsets were used instead which solved the problem.

Video: https://youtu.be/Ipm7DKHeySY

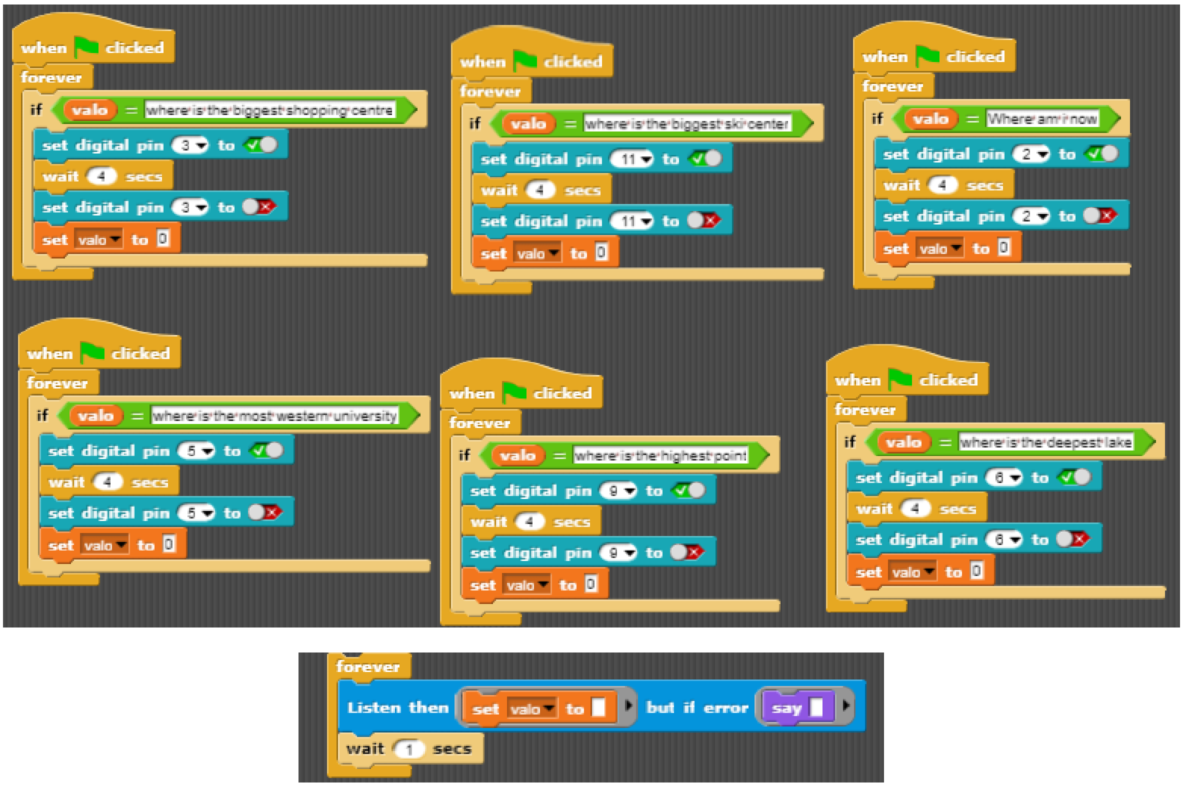


Figure 64: A program code of a map project where and LED lights up to show for example the location of the deepest lake on the map

4.18. INTERACTIVE ART PROJECT

For the 2nd round informal pilots 15-year-old students had an opportunity to create interactive art through eCraft2Learn ecosystem. Educators were introducing students to technically enhanced artwork with few videos of existing art ideas and students got very interested in creating their own technologically enhanced artwork. The idea was to use arts and visual expression as the starting point for the projects, thus initiating the work through arts. Then, to enrich the artwork with electronics and programming and to develop artefacts that could also be created without technology but adding technological components gives an entirely new experience with it.

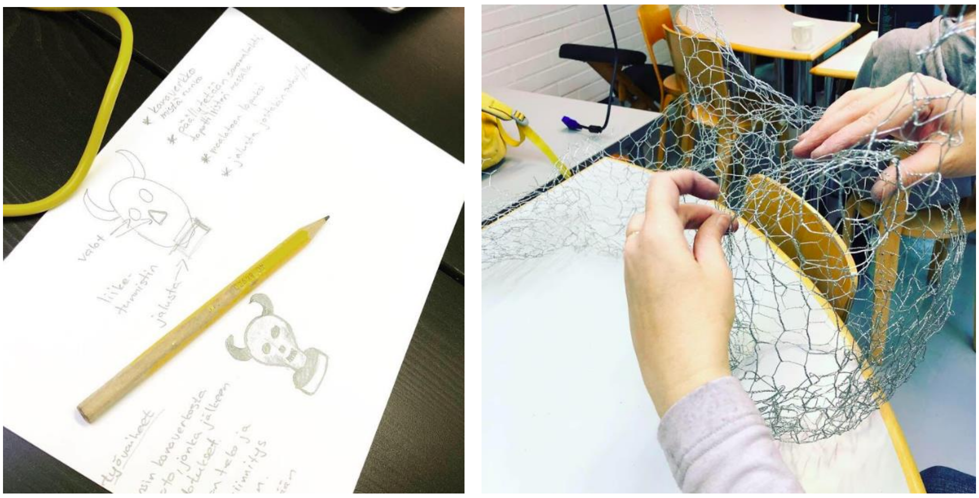


Figure 65: A plan for a head where the LEDs in the eyes turn on when a person gets closer, and the artwork itself in the creation phase

The interactive aspect was achieved by using sensors that detect the environment, such as touch, pressure or movement. Students created interactive art projects from their own perspectives and through their own unique vision. One student team painted a picture of space with stars and enhanced the painting by creating wirings for LEDs and programming these LEDs to blink in specific order when a touch sensor was pressed. Another student project was an artefact where pressing a button would move a high-fiving arm controlled with a servo motor. In a third student team students created a structure for LEDs and attached this structure to two servo motors. By programming the servo motors, the structure was moving through a specific path and moving the LEDs accordingly. In a dark room students then took a picture with long exposure time of the moved LEDs which led to beautiful long exposure photographs.

Some of the students had previous experience on programming with visual programming language and with Python but creating electronic circuits was unfamiliar for all. Generally, students were testing different wirings and programming codes without hesitation and searching for help from the internet for different sensors and actuators. After completion of the projects, the students' artwork was presented in an exhibition in the makerspace.

Figure 66: Examples of interactive art projects: a sky with stars (LEDs blinking when touch sensor pressed) and a high-five arm (arm moving with servo motor when button pressed)

Time allocated

Most of the groups completed the project within 10 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the creations
- foil, metal, chicken wire, paint
- Arduino Uno boards, wires, LEDs, distance sensors, touch sensors, servo motors

Technical details & software used

Student teams were operating through the UUI where a unique session ID was created by the educators (through the learning analytics) for this informal pilot site. Students were ideating with the Inspiratorium tool, sketching with eCraft Plan, creating 3D models with Tinkercad Circuit Design and programming their electronic circuits through Snap4Arduino. When using different LEDs, there was a discussion between the educators and one student team about how an RGB LED would work and would it be something this team would like to use in their projects. Though, this team decided to use normal LEDs instead.

The educators were monitoring group actions in the digital platform (UUI) using the teacher's interface, the learning analytics system. An issue that was noted in the first session was that the UUI was not sending to the learning analytics when a personally created session IDs were used. This was fixed by modifying the code in the UUI. Another issue that was noted was using analog distance sensors, as they produced very unreliable reading values due to interference in the environment. Some students managed to successfully use these distance sensors, but some student teams decided to use instead a digital actuator (such as the touch sensor or button) instead.

4.19. Smart Home Project

Another possible project topic for the 2nd round informal pilots in Finland was introduced as a smart home. The instructor led students to the topic by discussing what makes home a smart one. Students were thinking about already existing solutions used in houses, such as the remote lighting control or security systems. The possibility to use artificial intelligence in the student projects was also introduced to students. With speech recognition blocks the artefacts could for example turn on music when told. This project was a great link between the eCraft2Learn technical ecosystem and a real world and helped students to see how different systems can work and possibly diminish the uncertainties around technology in general by bringing different technological inventions closer to students.

One student team started ideating around the smart home topic and decided to create something that would work and could be used in real life too. The idea then progressed when students were experimenting with different sensors and actuators. Eventually, this student team built a lamp that detects movement and is on for 30 seconds when someone passes by it. This lamp could work as a night lamp in a house or as an environment friendly solution for street lamps.

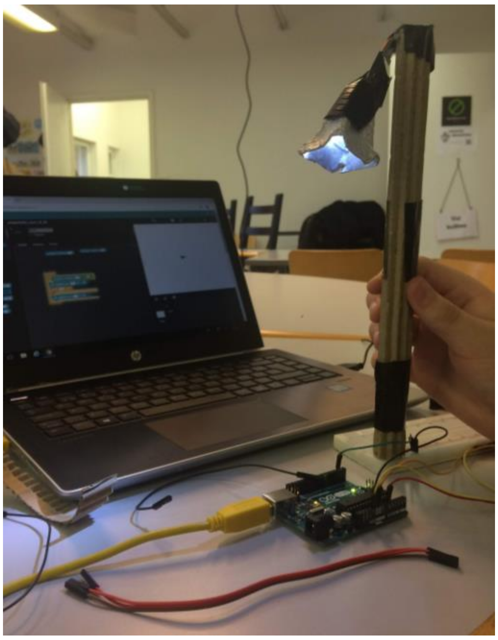


Figure 67: Example of a smart home solution: a lamp that turns on only when movement is detected

Time allocated

Most of the groups completed the project within 10 hours.

Hardware and materials that were used

- cardboards, recycled material and many different types of paper for making the artefacts
- foil, metal, paint
- Arduino Uno boards, wires, LEDs, distance sensors

Technical details & software used

Student teams started ideating with the Inspiratorium tool, created 3D models with Tinkercad Circuit Design and used Snap4Arduino as the programming environment. Students mainly used analog sensors with LEDs in their creations by reading the analog values and creating conditional statements.

5 GOOD PRACTICES VIDEOS

In this section, we summarize the good practices that were documented in the eCraft2Learn pilot sites in Greece and Finland and we list a number of video recorded episodes where most of these practices are reflected. An attempt has been made to thematically categorise the good practices based on the different stages of the learning process that they introduce. However, all the video exemplars of the good practices reflect aspects of the eCraft2Learn pedagogical model and methodology that are highly interlinked.

Table 11: List of videos

Short description of the recorded practices	Link in the eCraft2Learn YouTube Channel
Ideation & Planning These videos demonstrate the ideation and planning process, showcasing how the teachers supported the ideation process encouraging the students to review, analyse and share ideas in teams. The sharing of ideas in the plenary was another practice that took place that significantly boosted the generation of new ideas and the collaborative spirit in the eCraft2Learn labs. The students are seen to discuss their ideas, to identify pros and cons, to consider the material that will be needed and to discuss on possible solutions. The generation of ideas in most of the cases was followed with plans on paper, documentation and analysis through the UUI tools, draft sketches of the key steps to be undertaken and group discussions. The recorded episodes bring these practices into focus.	https://youtu.be/pOqfKEocHHs https://youtu.be/KASmme8jH08 https://youtu.be/ORXy8OlCy64

Short description of the recorded practices	Link in the eCraft2Learn YouTube Channel
Creating & Programming This video demonstrates episodes of the process of creating and programming the eCraft2Learn computer-supported artefacts. Episodes of the hands-on practices, the testing and experimenting are demonstrated showing the process that the students went through. Failures were part of this process calling for new ideas, new plans, problem solving and collaborative work.	https://youtu.be/uFbL76R_kPg
Teachers' role These videos demonstrate the role of the teachers during the pilot rounds in Greece and Finland; students' voices regarding the role of the teachers are also brought up. Teachers appear to encourage the students, to help discreetly, to raise dialogue, to act as co-learners and co-makers, to provide information and explanations when needed and to boost the 'can-do' attitude.	https://youtu.be/OtEsdBQjYKY https://youtu.be/SYl4kKr7vk0
Sharing These videos present how the important aspect of sharing was implemented. The following aspects are highlighted: ● Sharing in big events (such as Athens Science Festival 2018) showcasing their work and interacting with people of a wide range of ages and knowledge ● Sharing in the classroom/lab with a focus on ideas sharing, exchange of good practices and presentation of the current status of work ● Sharing online either experiences and created artefacts through social media or shareable parts of the work through the tools available in the UUI (i.e. 3D models through Thingiverse)	https://youtu.be/V6n360hagOQ https://youtu.be/6iqC4n1DW_Q https://youtu.be/TL3yhYfJnaA https://youtu.be/972r9HIYUV8
Playlist with 12 videos that showcase the eCraft2Learn projects that were carried out and described above (see section 4)	https://www.youtube.com/watch?v=QZHyYlv87no&list=PLgKtrHOACe-J6bvq-ka5ue4ERs142f4De
Full playlist will the 22 videos that had been created in the context of D5.5 showcasing both good practices and the eCraft2Learn projects	https://www.youtube.com/playlist?list=PLgKtrHOACe-I448iS4eAzpvFEbT3lDD20

6 Conclusion and Remarks

This report describes important episodes of the small-scale pilots that were carried out in Greece and Finland in the context of the eCraft2Learn learning intervention, both in formal and informal educational settings. These small-scale pilots allowed us to see how the teachers and the students acted and interacted in the eCraft2Learn ecosystem, what type of support was needed, what tensions existed, how the fun and the challenge of *making* and digital fabricating were perceived by them.

The support of the ideation process is among the good practices that were highlighted; the teachers tailored their roles and support to the needs of the students and discreetly empowered them so that to develop confidence and to start shaping their own ideas towards computer-supported artefact construction. The teachers supported the ideation phase with easy to start with projects and worksheets or with pre-defined by the curriculum topics moving the students to extend the project topics based on their interests and personal preferences. In addition, the teachers supported the generation of ideas during problem solving by raising prompt questions that could help the generation of ideas towards problem solving, providing useful explanations and boosting students' self-confidence and 'can-do' attitude.

The teachers that participated in the eCraft2Learn pilots were seen to play a key role towards the creation of meaningful *making* experiences. The sharing of ideas, practices and experiences was considered of great significance as it could inspire new and potentially innovative ideas for computer-supported artefact construction. A number of good practices for sharing were identified, which included the triggering mechanisms for sharing in the class (presentation of the current status of work and good practices exchange), in school events and well-attended festivals, in meetings with representatives of the scientific community, and online through the UUI and social media.

This report also describes the actual projects that were implemented by the students. The project scenario is described together with information about the time that was spent in each project, the materials and the hardware that were used, the eCraft2Learn tools that were exploited and the technical description of the solution. Most of the projects that were carried out were interdisciplinary in nature and focus on different STEAM related disciplines. Some projects were in line with formal school curricula, others were proposed by the teachers, others were the result of the extension or the personalization of a given project topic, while others came directly by the students. The projects may not be all innovative, but each project offered students unique opportunities to explore a rich set of tools and technologies offered through the UUI platform, to act in a team, to be creative, to challenge seeking, to fail and to keep trying, to be involved in problem solving, to communicate and share ideas with classmates but also with people of a wide range of ages and knowledge. Inspired by their eCraft2Learn experiences, some students were seen to re-program how they see school, homework and daily life, i.e. by critically requesting more time while in school for hands-on practices, by voluntarily continue their *making* projects at home, by scheduling meetings to discuss ideas for computer-supported artefacts at their free time in popular social places for youth.

As a matter of fact, in the context of the eCraft2Learn workshops, the students were observed to go through multiple processes: from idea generation, to planning, to collaborative hands-on construction, to problem solving, reflection, sharing, re-design and re-construction. All these processes were interwoven in the eCraft2Learn pedagogical model and learning methodology and ideally suited in the *making* process.

The iterative nature of the eCraft2Learn learning methodology allowed for reflection and helped students to see that failure is an important part of the learning process. The analysis of the failure and continuous improvement process was important for developing a growth mindset and encouraging persistence, challenge seeking, and learning. The eCraft2Learn constructionist format invites failure and exploits it in a didactic way helping students to understand it, to construct their own knowledge and to apply it in new situations and contexts. Within this iterative and constructionist format the students smoothly explored the available eCraft2Learn tools, technologies and resources for building and for thinking. The students based on the needs of their projects used the set of the tools provided through the UUI and involved in electrical circuit making, visual programming and AI programming, 3D modelling and printing and more towards computer-supported artefact construction.

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