eCraft2Learn

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

Deliverable D3.4 (M16)

Manual of Craft- and Project-based Learning STEAM Training for Teachers

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Authors:	**Calkin Suero Montero,** UEF
Contributors:	**Kati Mäkitalo**, **Mareena Hyypiä, Tapani Toivonen**, UEF
	Sonya Horton, ULTIMAKER | **Kenneth Kahn,** UOXF
	Rene Alimisi, **Dimitris Loukatos**, **Emmanouil Zoulias**,
	Dimitris Alimisis, EDUMOTIVA |
	Romain Herault, LNU | **Marcus Johansson**, ARD
Reviewers:	**Alex Jonsson,** EVOTHINGS

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EXECUTIVE SUMMARY

This deliverable D3.4 M16 shows an updated version and continuation of the work on the design of teacher training material presented in M8 (see Annex III). This deliverable designs, develops, implements and presents teacher education and training courses material taking into account all the aspects of the eCraft2Learn learning ecosystem. These aspects include 1. eCraft2Learn pedagogical core features, concepts and considerations; 2. eCraft2Learn technical core tools and software; and 3. practical steps to transform a curricular lesson into an eCraft2Learn task. This document also contains training schedules and guidance documents used during the teacher trainings for the eCraft2Learn small-scale pilots in Finland and Greece.

1 Introduction

This deliverable is a continuation of the work discussed and presented in M8 (see Annex III). The focus of this document is to provide a practical guide on the teacher training based on the theoretical background given in the previous version of this document (M8) and on the practical implementation of the teachers training in preparation to the small-scale pilot activities of the eCraft2Learn project. Therefore, this document has been developed taking into account the teaching and training orchestration provided in D5.1 Pilot protocol (see for example pages 24-25 of D5.1 for indicative training plans). The aim of this deliverable is to serve as a practical manual for pre- and in-service teacher education. During the practical teacher training workshops, emphasis was made to prepare the teachers to fulfil their role as coaches, scaffolders and facilitators of the learning experience of the students within the eCraft2Learn ecosystem.

This deliverable informs the development of the project through providing the needed capacity building to teachers to facilitate their understanding of the eCraft2Learn learning ecosystem. The document is structured in the same way as the capacity building and training workshops in Finland and Greece (see Annex I), covering the following topics: role of the teacher as a coach, personalised and adaptive learning through craft- and project-based pedagogical approach, hands-on familiarization with the UUI tools and the learning analytics and practical project building activities.

Notice that for clarity of presentation the document is structured in three parts: pedagogical training, technical training and how to transform a curricular lesson into an eCraft2Learn task. It is recommended however that the actual training integrate pedagogical aspects with technical activities in order to develop a holistic understanding of the pedagogical importance of each of the developed/deployed tools in the technical core.

2 eCraft2Learn Learning Ecosystem – Pedagogical Training

The eCraft2Learn learning ecosystem consists of a technical core, including physical and digital components and tools, as well as a pedagogical core to lay the ground of the craft- and project-based pedagogy. The training of the teachers on the pedagogical considerations of the project was carried out in closed integration with the use of the technical core (physical and digital tools) of the project (see Annex I for schedules and description of the training workshop activities within a series covering six training sessions in Finland and 5 training sessions in Greece).

2.1. Teacher's Role as a Coach

As part of the pedagogical considerations of the eCraft2Learn learning ecosystem, understanding the **role of the teacher as that of a coach** or facilitator of the learning experience is fundamental. When teacher acts as a coach, the focus shifts from teacher being the main actor in the classroom to the more student-centred approach where students have an active role in their own learning. A teacher can acquire the role of a coach when giving ownership to students and empowering them in the learning process. When taking a step back, teacher allows students to explore and find solutions to the challenges without providing direct answers. Thus, students will learn how to actively construct knowledge, rather than just mechanically copy and memorise the information.

As a coach, the teacher uses less the traditional front-facing teaching or lecturing and instead she/he strives to encourage students to choose their learning paths and to learn on their own or in small groups. The coach needs to understand that by giving more autonomy for students, he/she will not always be sure how learning situations will be constructed in the classroom. Sometimes this may lead to situations in which the teacher does not know the answer to questions that emerge from students. Accepting the uncertainty is the key to being able to coach students alongside their learning experience, not as an authority. It is also important to notice that support might be provided not only by the teacher, but it also can be given by other students who can have deep knowledge on the topic being studied and offer help on the same level as their peers. Hence, learning will turn into meaningful and engaging experiences.

The teacher's task is to guide and instruct students and provide them with real-time feedback. This can be done for instance by posing questions to students on how they have been working and what they have accomplished regarding their goals and objectives or by asking students to explain the choices they have made along the way. It is important to help students to self-monitor, self-evaluate and self-reflect on their own learning in order to help them to understand that the way of working they have chosen will lead to certain results. In this way, students are supported to become more self-regulated and in charge of their own learning processes. Moreover, the teacher as a coach identifies the individual support needs according to each student level of understanding and prior knowledge, thereby scaffolding the student in the learning process to foster every student to be proactive to acquire higher-level skills and knowledge. The successful implementation of these concepts will lead to creating personalised learning paths for each student.

Scenario Teacher as a Coach

Let us imagine a situation where a students' group wants to use a photoresistor but they are struggling because they do not know whether the sensor is an analogue or a digital one. One of the students decides to ask help from the teacher. The teacher starts by asking the student what it means to have analogue and digital signals. The student ponders for a while and recalls the session where they had searched information about digital and analogue signals from the open educational resources (OERs) through the eCraft2Learn user interface. The teacher encourages the student to explain this in his/her own words. The student remembers that the world is analogue as there are infinite values of colours, whilst a digital signal can only have values 0 or 1. The teacher praises the student for working hard to understand the concepts and asks if the student knows the functioning principle of a photoresistor. The student knows a photoresistor indicates when it is dark or light. The teacher continues: "Can the photoresistor have a range of values or only a value of 0 or 1?". The student makes his/her thinking process visible by explaining that a photoresistor can read different values from some specific range. The teacher nods and asks: "So, when you know all this, can you conclude a photoresistor is an analogue or a digital sensor?". The student arrives to a conclusion the sensor being analogue because it can read the amount of light in the surrounding environment and transform this light into corresponding numeric values. Teacher congratulates the student for putting effort for thinking and solving the problem and

Points of Reflections

From the teacher as coach scenario, can you identify the role of the teacher as a coach? Which strategies is the teacher using to allow the student to be the main actor of his/her own learning? How can you acquire the role of a coach in the classroom?

Tips to use in the classroom – Teacher as coach

- Plan a craft- and project-based eCraft2Learn activity where **students do not have any detailed instructions** on how to proceed. You can give broad guidelines on the topic or the problem. *What do the students need to create? How much time do they have?*
- **Engage the students** to ideate and plan their own projects. *What do they want to learn?* Ask students to create their own goals. *If requested, help students to work step by step by setting their goals.*

- **Map students' prior knowledge**. *This can be done for example through open discussions, mind maps or small quizzes, individually or in groups*. Understanding the background knowledge of the students will help you when scaffolding the students in their learning processes.
- **Give positive and constructive feedback to students**. *What are they doing well? How could they improve? How have they achieved their results? What kind of steps or processes were needed?* Give positive and specific feedback to students when showing that they are working hard and are engaged in the processes *(let the students understand what they did that deserved the praise)*
- When students have a question or a problem, **try not giving a direct answer**. Instead, **pose new questions, paraphrase the discussion** or try to **steer the conversation** in a way that students find out solutions by themselves. *Make them work and solve questions and problems in teams with their peers or discuss on how they could find the answer, what (online/offline) sources are available to use, etc*. Help students to discover the answer by themselves, not solving the problem behalf of them.
- If you do not know the answer for a problem, **honestly admit it**. Make this an opportunity to **learn with the students**, to create trust and improve the classroom atmosphere. *You can find the answer together, demonstrating the example that we do not know the answer to everything, but we can still find answers and solve problems*. This is what we call learning.
- *Your classroom is full of talented students and each of them has a unique variety of skills and knowledge*. Try to **empower the students to help their peers** and **learn from each other**.
- **Trust your students**. When you give them freedom and authority you will be amazed by how much intensity and effort they put into their work. **Embrace uncertainty , not knowing exactly what will happen next**. *New ways of working and learning take time to develop, do not give up!* Students as well will need time to get familiar with new working and learning. Be patient and be gentle to yourself and your students. At the beginning, students might need more help to adapt to these new working and learning ways, but it will be very rewarding in the end to see how much they actually learn and how deeply they engage and enjoy working and learning.
- **Assess the processes rather than the outcome of the product,** *helping students themselves to evaluate themselves, with peers and together with teacher/coach*

Points of Reflections

From the teacher as coach tips, how do you feel about being the coach of your students? Please note that the shift from being the main actor in the classroom to making the students as stars of the classroom is not always easy or happen fast, but be patient; the results will be worth the effort, as you will have creative, confident and engaged students!

2.2. Open Educational Resources (OERs)

The technical core of the eCraft2Learn has been designed and developed to assist the teacher in achieving the role of a coach by putting forward open educational resources (OERs) to facilitate students' independent work.

The OERs were developed with the main goal to gather resources from the World Wide Web (WWW3) that can be useful for students of all levels and familiarity with programming and e-craft projects. The OERs work at the same time as an "introductory gate" and a "filter" of all the information, tutorials and videos that are already available on the Internet, but must be found in the "Internet chaos" among other questionable online resources. Moreover, they work as a strong scaffold for students to explore the apps available in the UUI in each phase of their project. Hence, the OERs work hand in hand with the other tools offered by the UUI to give the most suitable and appropriate learning resources for students to develop their projects with autonomy.

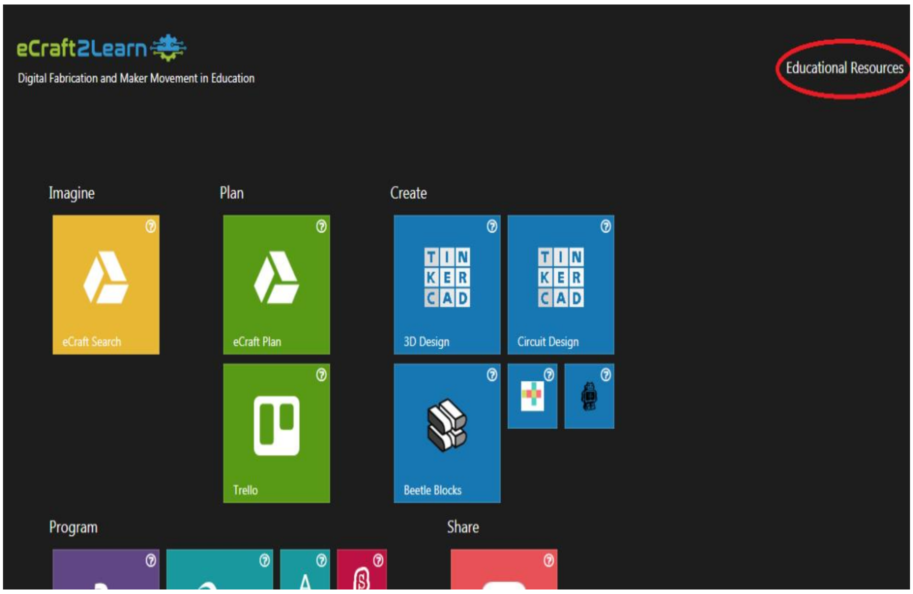


Figure 1. Access to OERs

In order to access the OERs from the UUI, the user must click on the Educational Resources tab, which is located on the upper right side of the homepage of the UUI, as indicated by the red circle of the Figure 1. When this tab is opened, a list of the OERs appear on the right side of the UUI homepage, grouped by the type of content.

Currently, the OERs are grouped in five types: Electronic Devices, 3D Printing, A.I. (Artificial Intelligence), Communities, and Troubleshooting. When one main group is selected, subgroups of

OERs appear under its name. Only one group of OERs is visible at a time. Hence, if the user selects the OERs for 3D Printing, the previous OERs that were visible disappear in order to give space for the new category selected.

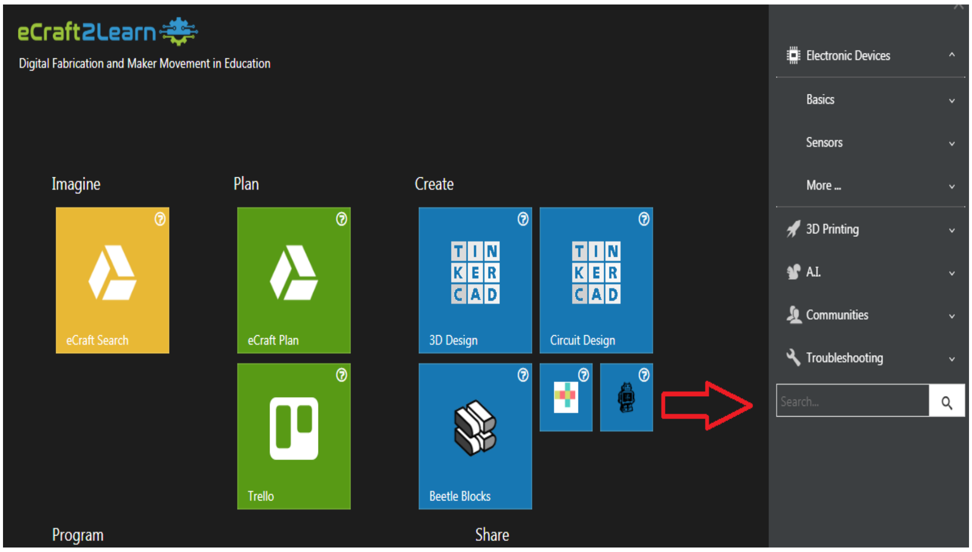


Figure 2. UUI search facility

If the user does not want to go through all the OERs types, but already knows what specific OER she/he is looking for, a **search facility** is available at the bottom of the OERs tab. This search mechanism can find any keyword present in any of the OERs. See the red arrow in the figure indicating the position of the OERs search facility.

The OERs, accessible through the Educational Resources tab, include resources with information on all **Electronic Devices** that are available to schools' projects developed during pilots of the eCraft2learn program. The Electronic Devices are grouped in 3 main groups: **Basics**, **Sensors** and **More…**

OERs on all **3D Printing** materials are also shown. These resources were developed by the eCraf2learn team and partners and they approach different topics of 3D printing, such as **Introduction materials**, **Cura videos** that explain how to print 3D models and **Ultimaker manuals**.

The OERs on artificial intelligence (**A.I.**) consists currently of one OER containing extensive materials (in format of links, both to teachers and students) to support non-expert programmers to start programming with AI blocks supported by the Snap! app.

The UUI also presents links and access through the **Communities** of practice to reach experts and the open community from the **Ultimaker Community**, **Arduino Forum** and **Arduino Wiki.** In case the user is facing any trouble or difficulty that the UUI materials and resources are not enough to support, the user can always ask for help, opinions, suggestions and feedback in these communities.

Through the OERs the users can also access the **Troubleshooting** section, which contains two subgroups: the **3D Printing troubleshooting** tutorials and the **eCraft2Learn troubleshooting components** from where the user will find some advices to deal with possible problems with the UUI resources.

Under each name of the main types of OERs described previously, the specific OERs appear. For instance, if the user clicks on the type **Electronic Devices --> Sensors**, all the sensors available are listed. If the user wants to learn about the sensor **Accelerometer**, she/he needs to click on it, opening a new window in the centre of the UUI, where information and educational links about accelerometer can be found. By clicking on the "Click here" button, the user can download (in .pdf file format) all the information contained in the OERs pages. Normally this button is located on the bottom of the window - exceptions are when the OER page requires lots of scrolling; then the "Click here" button will instead be located on the top of the window.

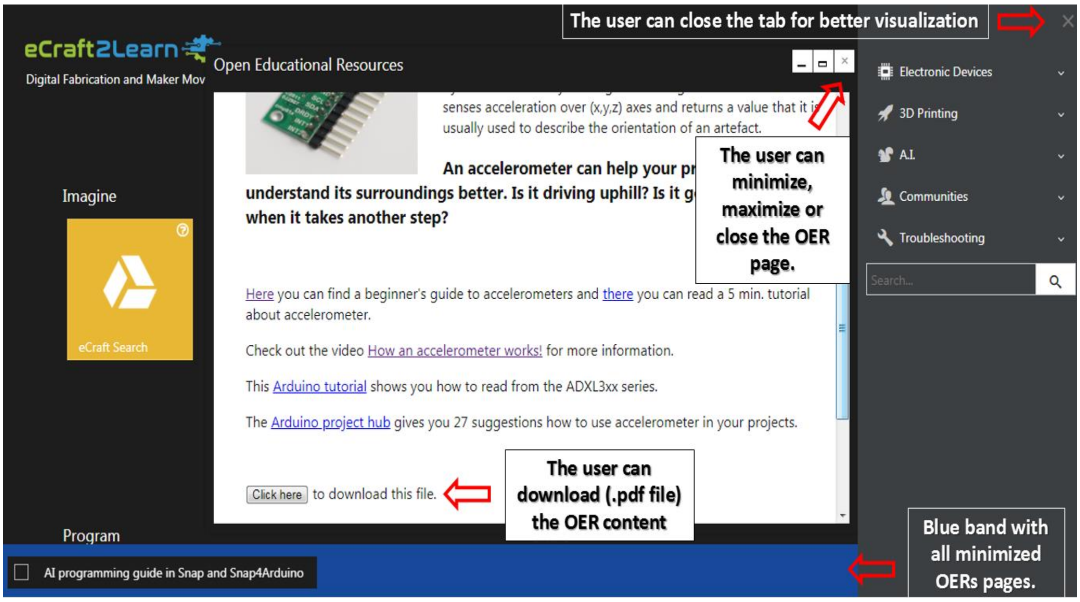


Figure 3. User interaction with OERs

The user can then close the tab of the Open Educational Resources in order to have a better view of the new window, as well as maximize and minimize the new window opened. In the case the window is minimised, it will be available to be maximized again in the blue band that appears in the bottom of the UUI. This blue band will contain all the OERs pages that are opened and minimized at the same time. Most of the OERs share the same characteristics described here (see Figure 3). In this video [https://www.youtube.com/watch?v=zu630uZLTuU&feature=youtu.be], the user can visualize all this process and explanations. Please note that the UUI is constantly improving the user experience and content. Hence, the menu **Education Resources** and some of the OERs described might change and/or expand, however the OERs will always be available through the UUI.

Hands-on practical scenarios

In order to practice and familiarize yourself with the OERs through the UUI, try the following scenarios:

1) Your team wants to use a breadboard to develop a circuit and connect it to your Arduino. How will you look for information about it?

2) You never used a 3D printer before and you want to learn more about an Ultimaker printer. Where will you look for information about it in the UUI?

** Please, note that the UUI is a dynamic platform that contains different information through different materials, apps and resources. There are no one absolute right answer!*

2.3. Pedagogical Model

As part of the pedagogical considerations, the teachers/coaches are also trained on the **craft- and project-based pedagogical approach** that the project is putting forward. The methodology is based on a five-stage project-based learning pedagogical approach: ideation, planning, creation, programming and sharing. This approach is in itself based on ideas of inquiry- and design thinking-based approaches. Within project-based learning, students have the freedom to choose the subject matter and to define the central content of the project they want to work with. It is important that the projects can be linked to the authentic contexts of the real world. During the training it is emphasised that a way to achieve this within formal education context is to transform a given a topic/lesson into an eCraft2Learn task. For this activity the "Quick Teacher's Guide - How to Run an eCraft2learn Activity Task" is provided and discussed in depth with the teachers during the training (see Annex II).

Within the training, attention is also given to the understanding and fostering of **personalised learning path** for students as part of the role of the teachers as coaches. This goes hand in hand with scaffolding and supporting the development of **21st century skills** through craft- and project-based tasks. Teachers/coaches are given in-depth information on the use of each of the digital tools available for each stage of the pedagogical approach and accessible through the unified user interface (UUI), the digital platform of the project. Information is also given on how these tools are expected to support pedagogical processes such as collaboration and cooperation - negotiation and communication - creativity, critical thinking, problem-solving as well as learning to learn skills and the ability to use technology and engage in contextualized school lesson tasks. During the training, emphasis is also made on the engagement and retention of girls into the eCraft2Learn tasks and activities through the utilization of arts and handcrafts combined to develop their solutions to the posed problems in a collaborative team effort (see STEAM discussion, D3.4 M8, section 1, Annex III). Figure 4 shows the relation between the pedagogical stages of craft- and project-based methodology and the tools put forward in the UUI.

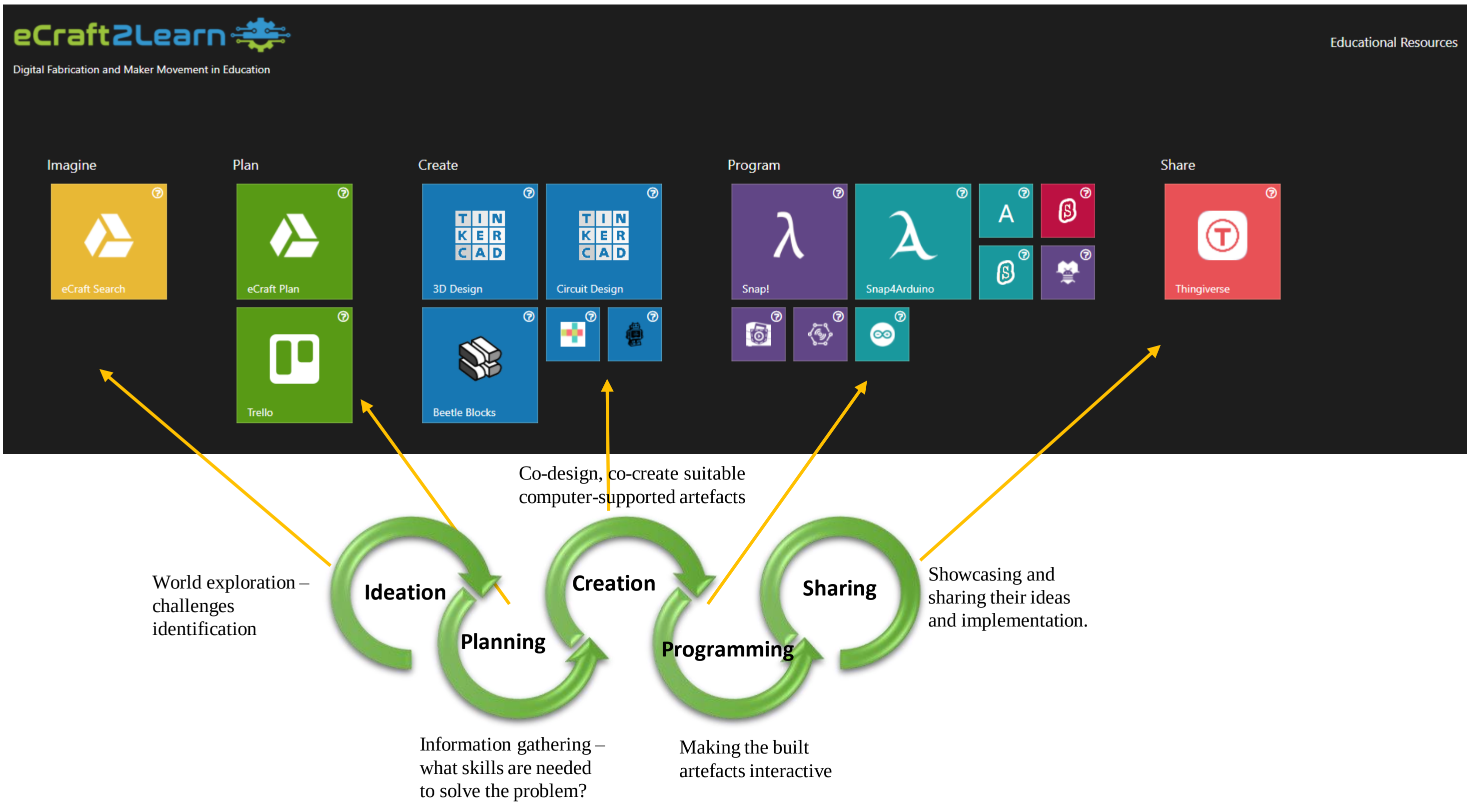
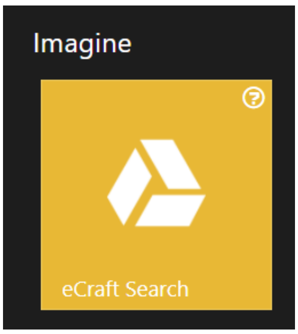
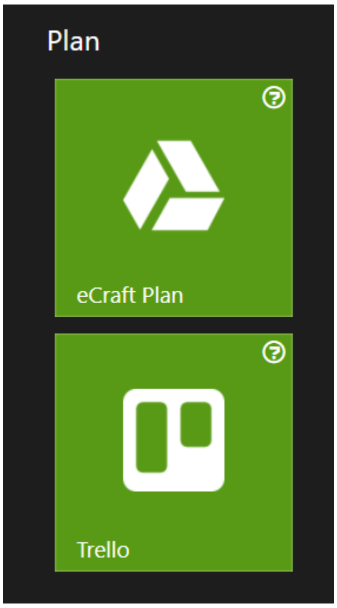
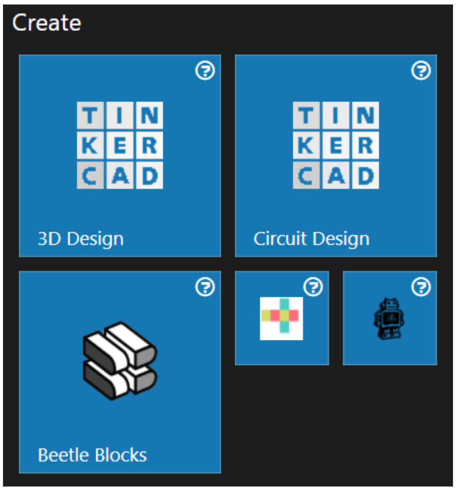
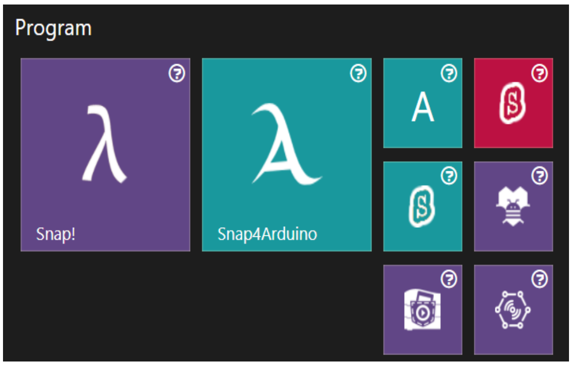


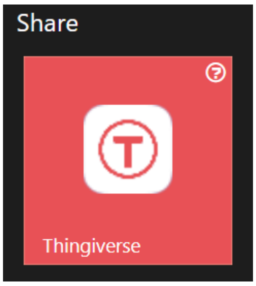
Figure 4. Pedagogical stages of the craft- and project-based methodology and digital tools to support them

Table 1 shows the description of the pedagogical considerations of the tools for each of the five pedagogical stages.

Table 1. Digital tools and pedagogical considerations

Pedagogical Stage	Pedagogical considerations of the tools
	The Imagine stage is represented by a native search tool, eCraft Search. The aim is to facilitate the ideation process by providing suitable examples from where to see what is possible (e.g. learning by example). We work under the assumption that imitation fosters inspiration and can lead to innovation – the students are to self-regulate what can be imitated and what can be improved in the produced examples.

Pedagogical Stage	Pedagogical considerations of the tools
	In the Plan stage two tools are put forward a) A native sketch tool, to draw, use pics, and add text, eCraft Plan b) Trello, a project management tool. *(Note: this is being recommended to be updated to a lighter version of a planning tool to record tasks, person assigned to and stages of task development (on going, stuck, completed), as well as audio recording capabilities).* With these tools we aim at supporting teamwork, responsibility taking, self-regulation, self-awareness as well as collaboration skills
	In the Create stage we are putting forward 3D design and circuit simulators (computer aided design, CAD, tools) as well as BeetleBlocks, which provides a similar environment to the programming tools (i.e., programming blocks to create a 3D model). With these tools, we aim at supporting creativity and problem-solving skills
	In the Program stage we are putting forward visual programming tools (Snap!, Snap4Arduino, Scratch, Ardublock, etc.) as well as the App Inventor programming environment. The aim with the visual programming tools is to lower any preconceived resistance to programming as well as accelerating the learning curve of novice students.

Pedagogical Stage	Pedagogical considerations of the tools
	Thingiverse – a community of practice for sharing 3D models created through TinkerCAD, for instance, represents the Share stage. *Note: in this stage a native tool is being recommended. This tool is to be developed based on the teachers' feedback about what it is important to share at the end of or during an eCraft2Learn activity task* The aim is to support and foster students' presenting and communication skills, as well as assist them in enhancing their thinking by showing and sharing different approaches and perspectives to the same problem

2.4. Students' Self-Regulation and Self-Reflection – Towards Personalised Learning Paths

We want to prepare students for the future requirements of a digital society, at school and at work, help them realise their potential and strengthen their abilities to be in charge of their own learning. A personalised learning approach provides opportunities for students to be autonomous and develop their self-regulation skills through suitable scaffolding from the teacher as well from the peer learners. Self-regulated learning (SRL) includes strategies for recognition, monitoring and control of learner's behaviour, cognition and emotional reactions in learning situations (Hirvonen 2013, p. 569). The learners' goals direct their behaviour as they try to match goals, actions and inner states in relation to the demands of the environment (Järvenoja & Järvelä, 2006, p. 86; Pintrich, 2000, p. 452). This is directly related to self-awareness process. Self-awareness develops throughout the life span of the individual (Demetriou and Kazi, 2001), and in turn it influences the development of self-efficacy - what the individual believed she or he can do with their skills under certain conditions (Maddux and Kleiman, 2012). The teacher in their role of a coach need to regulate the learners' self-evaluation (of their ideal goals against their real states) that goes in hand with the self-awareness process so it does not lead to self-criticism and negative affects, which in turn is reflected in low self-esteem (Davis and Brock 1975) leading the undesired way to frustration or demotivation. Rather teacher is guiding student to think their actions and the consequences of the actions to the results achieved. Teacher make students aware that by working hard they will get the results by praising the students who are engaged in the activities and are putting effort for processes.

From the various models of SRL, three main phases are recognized, which Puustinen and Pulkkinen (2001) identify as *preparatory*, *performance* and *appraisal* phases. In the *preparatory phase*, learners are making metacognitive choices such as task planning and goal setting that are based on learner's self-knowledge and motivational beliefs. The *performance phase* includes the use of chosen strategies, self-regulation and reflection where the learner is directing the activities by monitoring progress in relation to goals and conditions. The *appraisal phase* consists of self-reflection and performance feedback, in which the learner reflects on the efficiency of activities, outcomes and strategies. These phases are also linked to Pintrich 's phases of self-regulation: 1. forethought, planning and activation (*preparation*); 2. Monitoring and 3. Control (*performance*); and reaction and reflection (*appraisal*) (Pintrich, 2000).

In order to create a strong pedagogical core the three SRL phases are included into the pedagogical model of the project as shown in Figure 5. With this, we aim to foster the sustainable inclusion and use of technology for *making* into the education arena, as well as to support personalised learning paths within the eCraft2Learn ecosystem. As the SRL phases are cyclical in nature, they will be guiding the activities of learners in each stage of eCraft2Learn pedagogical model in order to enhance the learning process so that the learners are *learning to learn*, beyond only learning by doing.

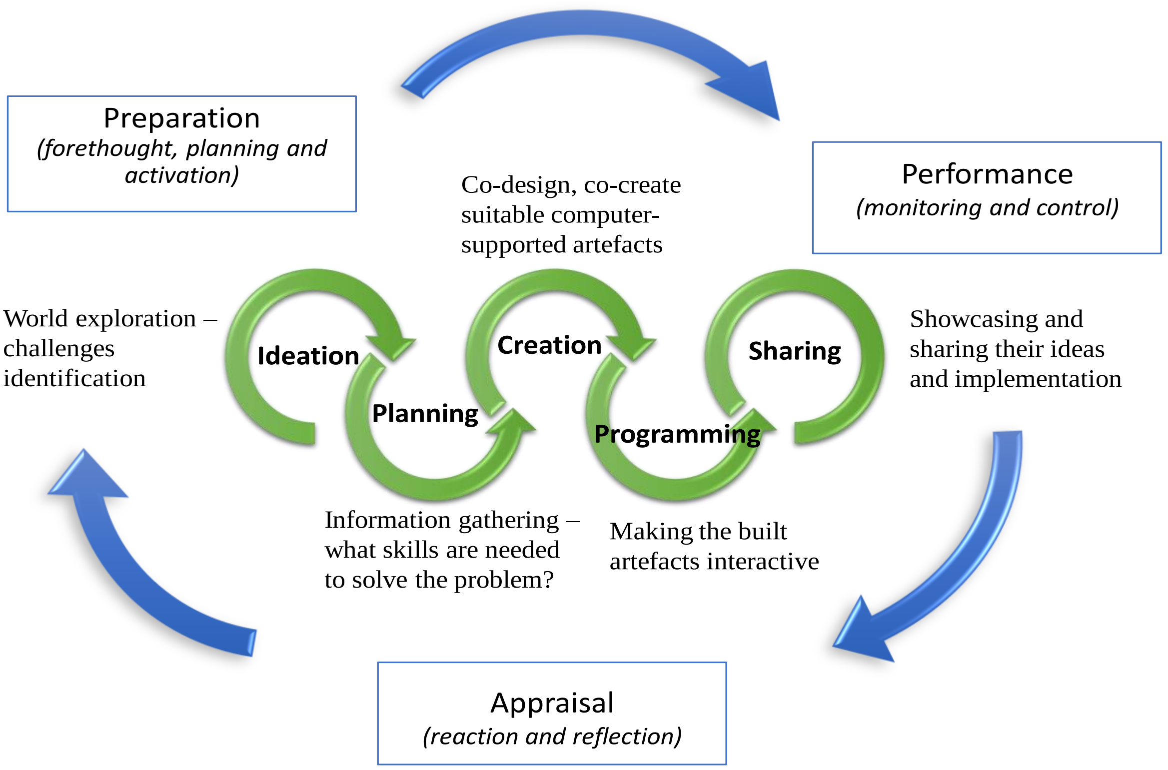


Figure 5. eCraft2Learn pedagogical core integrated with SRL phases. Each of the pedagogical stages is interlinked with the SRL processes of preparation, performance and appraisal

Table 2 demonstrates the processes that occur under each of the SRL phases, from the perspectives of the students' and teacher' actions, suitable teaching methods and scaffolding questions. In the five stages of the eCraft2Learn pedagogical framework, different support strategies can be identified and targeted to promote students' SRL. Table 2 also provides guidelines on how a teacher/coach can support learners' SRL through the different stages of the eCraft2Learn five-stage pedagogical model.

Table 2. Self-regulated learning processes

	Preparation ***(forethought, planning and activation)***	**Performance** ***(monitoring and control)***	**Appraisal** ***(reaction and reflection)***
Students' actions	• Engaging, exploring, discovering • Understanding the context, *('why am I doing this task?')* • Activating prior-knowledge and schemas	• Deepening understanding *('what do I need to do in order to accomplish this task?')*	• Sharing expertise and experience *('how am I feeling about this task?')*
Teachers' actions	• Creating opportunities to facilitate engagement and motivation • Providing basic information • Scaffolding students learning experience while they plan their work • Maintaining a balance between teachers' control and students' freedom	• Fostering student led learning and peer learning • Encouraging students to find, understand and use their own strengths • Scaffolding the process through open-ended questions and cues to help students solve problems • Motivating students to model their thought processes through feedback and positive self-talk • Maintaining a balance between teachers' control and students' freedom	• Providing sufficient time for teacher-, peer- and self-assessment • Scaffolding students' reflection on their feelings and experiences during the learning process • Encouraging students to share and compare their reflections with others • Approaching failures as opportunities for learning: encourage students to talk about failed attempts and together identify the lessons learnt.

	Preparation ***(forethought, planning and activation)***	**Performance** ***(monitoring and control)***	**Appraisal** ***(reaction and reflection)***
Teaching methods	• Discussions in class or in small groups • Demonstrative videos pictures • Mind-maps • Experts visits to the classroom and students visits to companies • Teaching plans (materials, timing, roles of students)	• Hands-on collaborative work • Cooperation	• Discussions • Presentations • Learning diaries • Blogs • Lessons learnt from failed attempts
Guiding questions *(scaffolding)*	• **Task/content related questions:** *"What is the topic about?"* *"What would you like to know about it?"* *"How does it relate in your life?"* • **Supporting self-awareness/ regulation questions:** *"What do you know?"* *"What will you learn?"* *"How do you learn?"* *"What will you do?"* *"When will you do?"* *"What are your learning goals?"*	• **Task/content related questions:** *"Tell me more about it."* *"What is the problem?"* *"Where should we look?"* *"What do you want the artefact to do?"* • **Supporting self-awareness/ regulation questions:** *"How are you performing related to your goals?"* *"What kind of learning strategies are you using to reach your goals?"* *"What is supporting/ obstructing your progress towards your goals?"*	• **Task/content related questions:** *"What kind of problems did you face? How did you solve them?"* • **Supporting self-awareness/regulation questions:** *"How did you work?"* *"What did you like the most/least?"* *"What did you learn?"* *"Did you achieve your goals?"* *"What did you do in order to learn?"* *"Were these results due to my efforts?"* *"What will you keep/ change in the future?"*

Teachers/coaches can support students to become conscious of their learning processes by fostering their metacognitive skills and promoting SRL. For this***, it is essential to create an environment that provides various learning opportunities***. (Perry & Rahim 2011, p. 125). Hadwin, Järvelä and Miller (2011) remind that these opportunities should build on learners' previous knowledge and the tasks should be challenging enough to motivate and engage students in their own learning processes. Students should have the control over their learning as they can make meaningful choices or decisions and set goals (Kontturi 2016, p. 153). Moreover, formative student assessments have an important role on fostering SRL. Not only should the assessment come from teacher to student, but tasks should also ***include opportunities for peer- and self-assessment to enable students to reflect and monitor their own progress***. (Kontturi 2016, pp. 41-42).

Newman (2008) suggests that an atmosphere where asking and giving help are seen as valuable skills support SRL best. Not only a teacher but also peers can pose questions and provide answers. Notice, however, that from the learning perspective, it is necessary to consider and limit the type of help and feedback provided to the learner (Mäkitalo-Siegl et al., 2011; Paris & Paris, 2001). Nevertheless, support should be sufficient so that learners are able to complete the task and achieve learning goals (Newman 2008, p. 316). Therefore, the teacher or technology-based prompts or other peers/learners should give suitable feedback to learners at appropriate times (see Mäkitalo-Siegl et al., 2011). Thus, the support should be tailored to learner's needs by scaffolding the learner through the learning process. As Paris and Paris (2001, p. 91) remark, reflective discussion about the task and possible solutions have more impact on enhancing the learning strategies than giving direct instructions or answers.

The eCraft2Learn digital platform is designed to provide support for student's self-regulatory and self–reflective processes and thus to create personalised learning paths. It is important to bear in mind that when working in groups, each group can create their own personalised learning path - this is not restricted only to individual students. Then the group is who is planning and designing their own steps in their personalised path. The teacher should acknowledge that every learner, and when working in groups, every group, will have their unique way of working. After each work session using the UUI (digital platform of the project), the platform requires the student to reflect back on the activities and goals by asking few questions. These questions aim at both helping the student to reflect on the work done and providing essential information to the teacher to guide and personalise the teaching better.

Hands-on practical scenarios

Teachers/coaches must create opportunities for students to reflect on their own learning. These opportunities should support students to:

a) Monitor and evaluate their progress in relation to their goals *(e.g. Am I doing appropriate tasks to reach my goals?)*
b) Reflect on their value expectations *(e.g. Do my efforts focus on right tasks?)*
c) Evaluate the effects of aiming towards the goal *(e.g. what are the benefits/costs for me or for the others?)*
d) Reflect on the importance of their own work *(e.g. were these results due to my efforts?)*
e) Take their experiences into future learning situations *(e.g. what will I keep/change in the future?)*

(Kontturi 2016, pp. 38, 154).

Points of Reflections

As self-regulated learning (SRL) is a combination of individual, social and contextual aspects, teacher must consider these dimensions when planning, implementing and reflecting on the type of support to provide for learners. The role of society in SRL is highly important as the learning environment and atmosphere have a big impact on each learner's SRL.

2.5. Learning Analytics

Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs. Within the eCraft2Learn learning ecosystem, the digital platform UUI also includes learning analytics tools, the advantages of which are being investigated.

The purpose of the analytics tools is to assist learners and teachers/coaches in the five-stage process by providing suitable information and visualisations. The analytics tools can track learners' activities within the digital platform UUI, and offer immediate visual information regarding the students' progress to both the teacher/coach and the students. A dashboard showing relevant information, such as the time used in each pedagogical stage, for the learner can motivate and guide the learning process. The analytics tool can also prompt learners to try working with another tool within the UUI or to search help from suggested open educational resources. Furthermore, it can identify who are performing well in a student body based on the teachers/coaches defined criteria and predict who will be in need of extra support. In this way, the learning analytics tools aim at assisting the teacher/coach pedagogical understanding of the situation and their guidance to the students. To classify the students, the teacher is required to train the classifier before the automatic classification can take place. See the learning analytics in practice described in Sect 3.8.

3 eCraft2Learn Learning Ecosystem – Technical Training

During the training, the teachers are given ample opportunity to tinker and interact with the technical core (physical components and digital platform); from establishing the connection between RPi3 computer board and an Arduino Uno board to familiarizing with the programming environments (Snap! and Snap4Arduino) and with 3D design and printing software. These activities are integrated into the development of a given example task that the teachers need to solve by going through the 5 stages pedagogical approach: ideation, planning, creation, programming and sharing, in the same way that the students would do in their classrooms.

3.1. Setting the Technical Core and Digital Platform

After the introduction of the eCraft2Learn pedagogical framework, the Raspberry Pi (RPi) computer and its functionalities are introduced. The training then continues by asking the teachers to set their technical core with the physical components by setting the RPi3 with the peripherals components (i.e., mouse, keyboard, monitor, etc., see Figure 6. Setting the 3D printing is not performed at this point).

The reasons why using a Raspberry Pi (RPi) are also explained (e.g., low cost, low energy consumption, etc. see D4.2 for an extensive description). The RPi3 has already pre-installed the needed plugins for google Chrome to operate properly the UUI[1]. Once the RPi3 is set then the teachers are asked to connect it to the Arduino Uno board provided and check whether it is possible to communicate with the Arduino board launching the UUI Snap4Arduino application.

[1] If for some reason this is not done, the Chrome extension and explanation how to install it in the browser are accessible through the Troubleshooting – eCraft2Learn Components of the OERs in the UUI

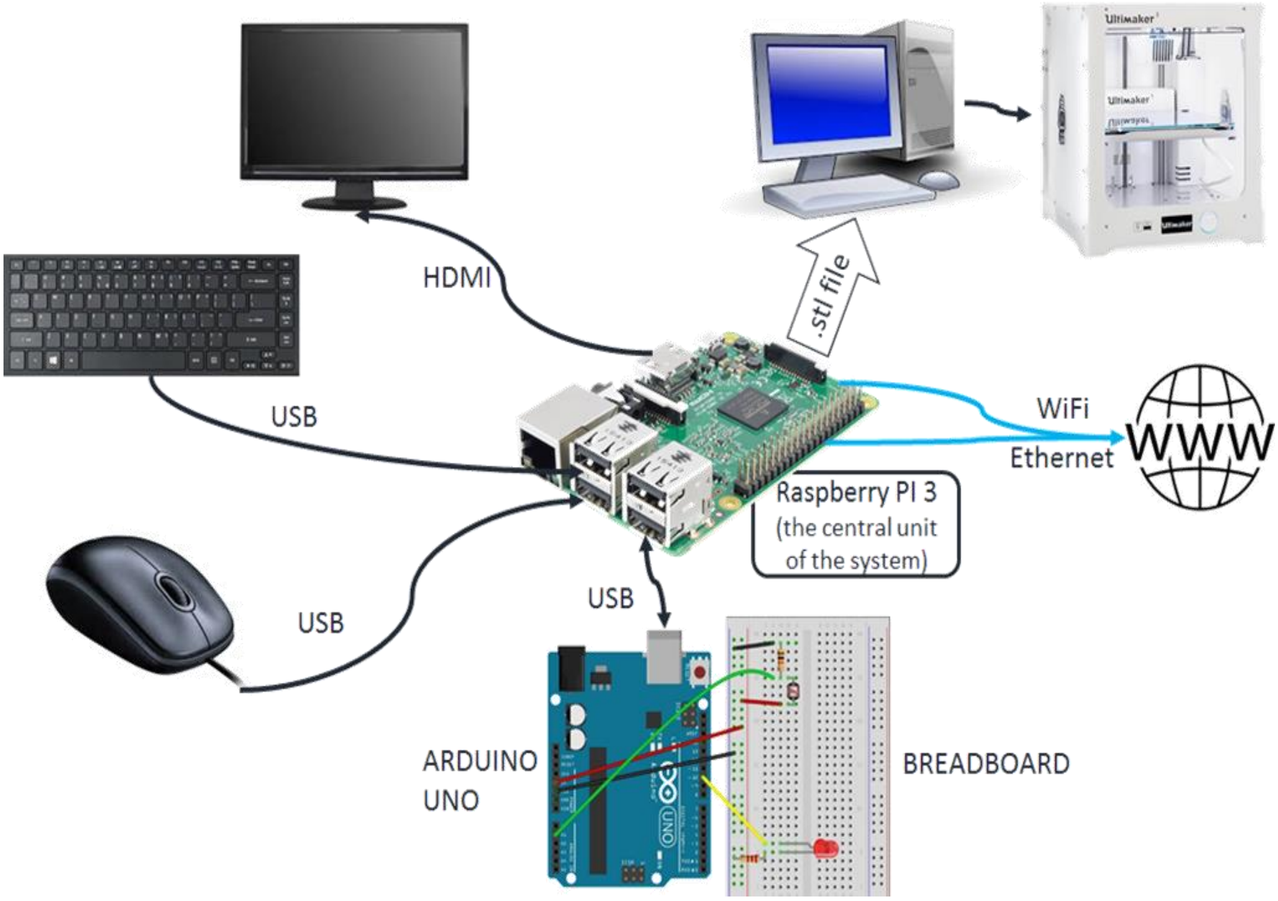


Figure 6. eCraft2Learn technical core based on RPi

Once the connection between the RPi3 and the Arduino board is established then it is also advisable to login to TinkerCAD (or to create an account if they have not done so)[2]. After login in to TinkerCAD, the application can be launched and used from within the UUI. It is important to use the digital tools by launching them through the UUI; this is useful for learning analytics data collection purposes.

After the technical core (or a suitable PC/laptop) is working appropriately, the training continues with explanations and hands-on activities on the digital tools available through the UUI for each pedagogical stage.

[2] We advised the teachers participating in the pilots to create one common account that they could share with their students groups for working with their 3D designs and 3D circuits simulations

Hands-on troubleshooting

If during the setting of the connection between RPi and the Arduino board problems happen then the following is advised:

- If Snap4Arduino programming environment launches but cannot connect to the Arduino board, then the browser needs to be changed to Chrome or a Chrome extension needs to be installed. Instructions on how to do this are given through the UUI Educational Resources - Troubleshooting - eCraft2Learn Components
- If the browser is the recommended one and the proper extension is installed but still there are connection problems then the connection needs to be reset by disconnecting and reconnecting the USB cables
- It is always advisable to disconnect the Arduino board after finishing using Snap4Arduino

3.2. Ideation Stage Tool

For the ideation stage, a native tool that can be used to find and generate new ideas for projects has been developed. The **eCraft Search** tool uses several APIs including YouTube and Flickr to offer pedagogically suitable videos and images for the students. The main idea behind the search tool is to offer safe search results of educational materials where the students could look for innovative ideas or search for additional tips for their projects. The APIs that the search tool uses were selected so that only educational material will be shown to the students.

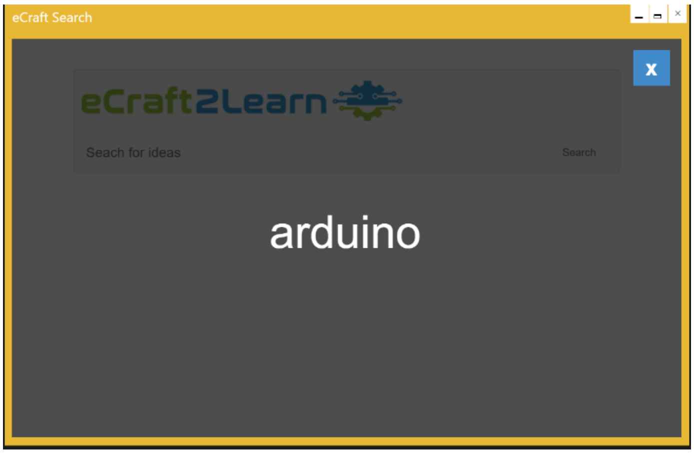


Figure 7. eCraft Search tool

The search tool is accessible from the Imagine area (ideation stage) in the UUI. The student can use the preferred keywords in the search field. After the search, the system will show the related video clips and the pictures for the student who can then select the preferred ones to include them later on the “Share” tool. Figure 7 shows the user interface of the tool.

3.3. Plan Stage Tools

There are two native plan stage tools. First, a **sketching tool to draw** a more detailed plan. Notice that this tool **can be also used in the ideation stage** (Imagine area of the UUI), where the students can draw and write down the ideas that they generate. Figure 8 shows the user interface of the tool. The sketching tool includes the possibility to upload images (for instance from the search tool) and to edit them.

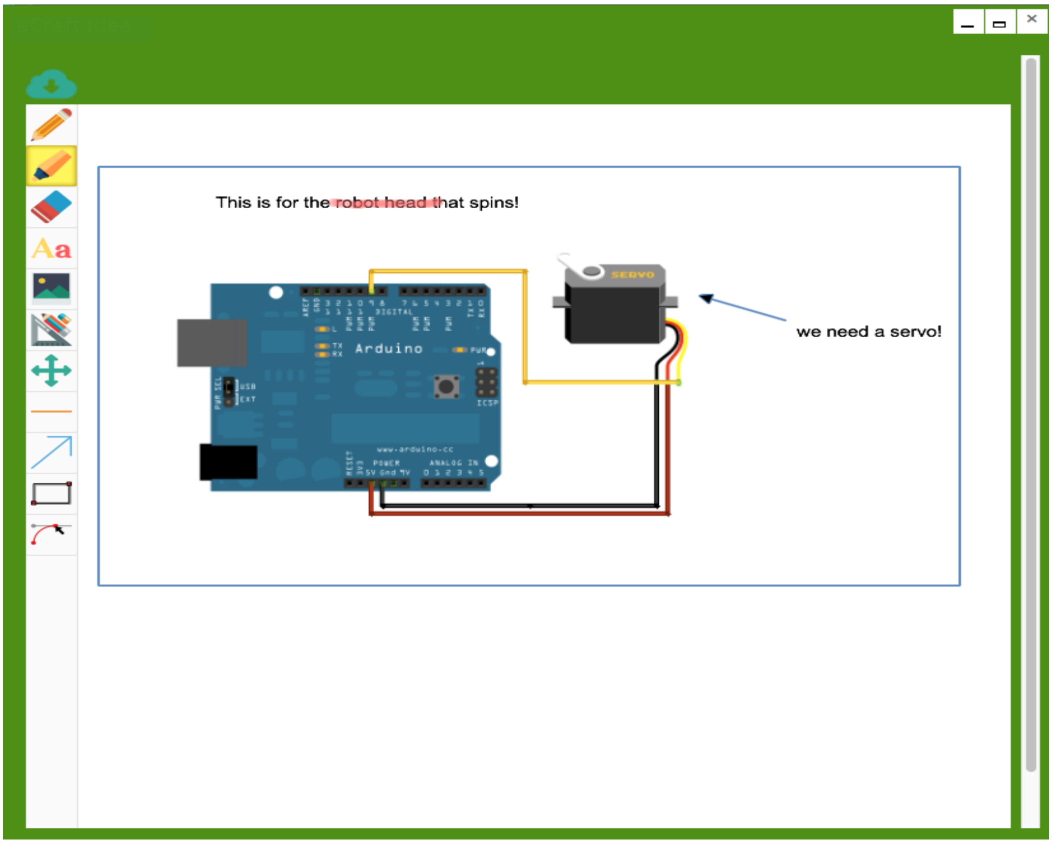


Figure 8. eCraft Sketch tool

The tool also includes other options, like drawing rectangles and circles for instance. The idea of the sketching tool is to allow the students to freely ideate and draw the sketches about their projects.

The second tool in the Plan stage is a **TODO-app**, under development and aimed to be a light version of Trello, as per recommendations (see D5.3). The TODO-app will list all of the individual students related to the projects. For each student, a user of the TODO-app can assign a task written with a rich text-editor (TinyMCE). For each task, it will be possible to upload recorded sounds such as speech, images such as photos as well as videos. After the task created is assigned to a student, the student for whom the task has been assigned can edit the task, change its status ("completed" | "under progress" | "stuck"). All of the tasks will be shown to every member of the student group participating to the project (see Figure 9). The purpose of the application is allow the student plan the project in a detailed and organized way.

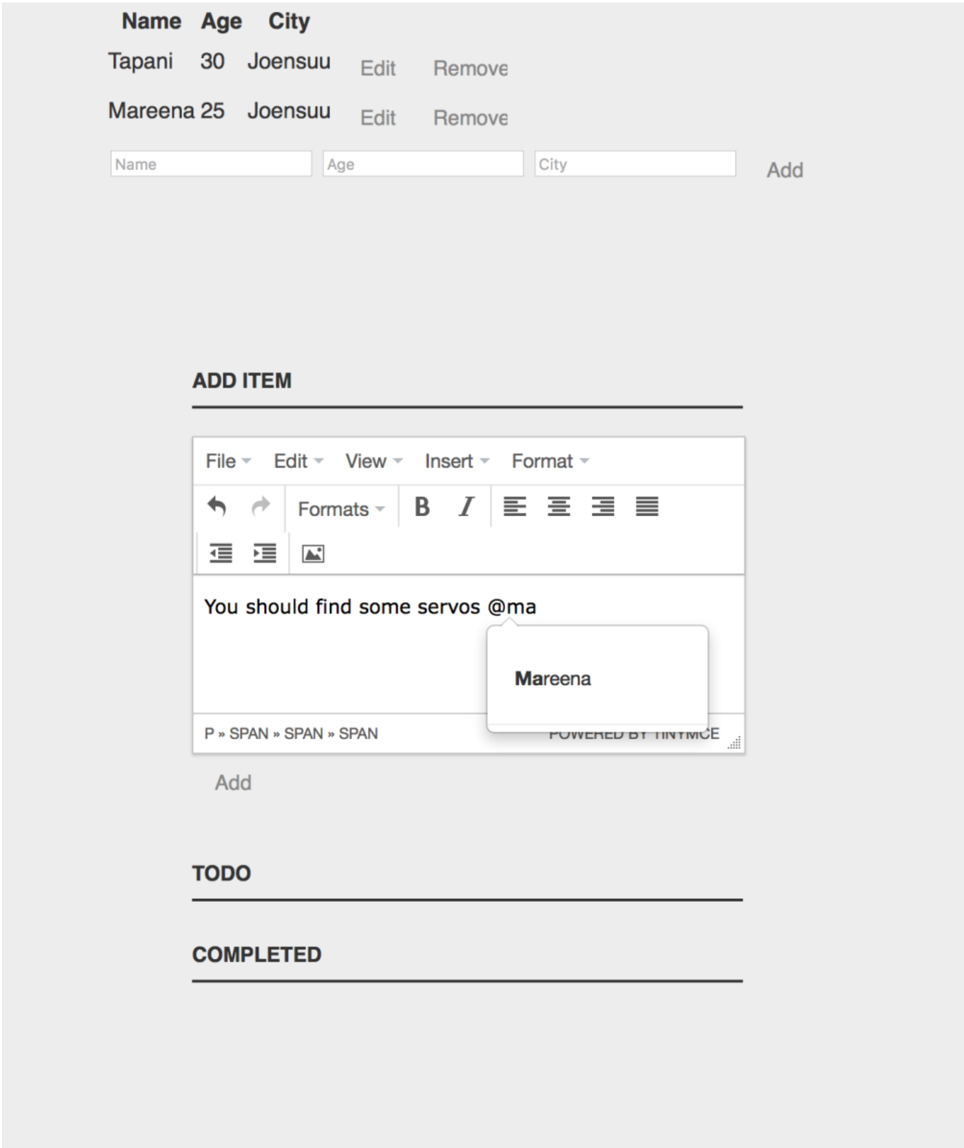


Figure 9. TODO-app (under development, the layout might change for the final product)

Because the tools in the Ideation and Plan stages are native tools within the UUI, they also collect interesting events from their usage. The interesting events include mouse clicks, search terms, search results, and the tools used in the sketching tool. The teacher can later observe the analysis of these events within the learning analytics.

3.4. Create Stage Tools

At this stage, the different parts that comprise the artefact are designed, assembled and brought together. This stage may include hand-crafting, wiring the Arduino board and making the necessary sensor connections and Computer-Aided Designs (CADs). When referring to hand-crafting, we are referring to a creative process that involves a variety of work for creating useful and decorative objects which are made by hand or by using simple tools. Hand-crafting has an important place in the eCraft2Learn projects. Crafting material (e.g., paper, card stock, sheets of heavy paper, foam, buttons, wooden sticks, and more) and simple tools (e.g., scissors, silicone pistols, rulers) can be used for the creation of the models or generally for enriching the construction. Figure 10 shows part of this creative process.

Regarding the use of CADs, this is supported in the eCraft2Learn digital platform UUI through TinkerCAD, an easy and browser-based 3D design tool. TinkerCAD requires a user account. A number of tutorials are available in the UUI to guide teachers in preparing their 3D models in TinkerCAD. It is recommended to start exploring 3D modelling in TinkerCAD through simple tasks that smoothly introduce the several features and tools to the user (see Sect 3.XX for detailed hands-on exercises). The main idea behind 3D modelling in TinkerCAD is the concept of “divide and conquer.” This means that the object to be 3d modelled should be divided it into smaller geometric shapes/figures. Each geometric shape should be designed individually and in the final step all the shapes should be brought together. In other words, the final object is analysed from a geometrical perspective, divided in smaller units, which are 3D modelled and grouped together in the end. For familiarisation purposes, simple tasks can be performed where the users identify the smaller units in object and use the available tools to create the 3D model.

Once the model is ready, it can be saved as a *.stl* file and imported to Cura software. Cura is the slicing tool used in the eCraft2Learn ecosystem for preparing gcode files to be 3D printed. The 3D printed object can be used to support/enrich the main construction or can substitute key parts that have been paper-modelled. More details about the 3D modelling, slicing and 3D printing process are described in section 3.7.

Photo by Anna Talkkari

Figure 10. Crafting tools and material used and created artefacts through hand-crafting during pilots

3.5. Program Stage Tools

Student projects involve artefacts that *do something*. They might turn on and off lights, motors, sounds, and more. The behaviour of the artefacts may be influenced by sensor readings that measure sound, light, heat, pressure, and much more. The program stage is when the students design, implement, and test programs to do what is called *physical computing*.

3.5.1. Snap! and Snap4Arduino

While there are hundreds of possible programming tools only nine have been integrated with the UUI. These are Snap!, Snap4Arduino, Ardublocks, Scratch4RaspberryPi, Scratch4Arduino, MIT App Inventor, Pocket Code, NetsBlox, and Arduino IDE. We have focussed the majority of efforts on Snap! and Snap4Arduino. Scratch offers little over Snap! and its variants and is less powerful and much less extensible. Snap! is largely compatible with Scratch. The many students who have had prior experience with Scratch have no problem using Snap!. Ardublocks is not our focus since there is no web version. MIT App Inventor and Pocket Code are focussed on mobile devices. NetsBlox is a Snap! variant that supports access to open data sources. The Arduino IDE is much more difficult for beginners to learn and master.

Snap! is an open source blocks-based programming language supported by the University of California, Berkeley and SAP (see Figure 11). Snap4Arduino is a variant of Snap! extended to provide control of Arduino devices. Both versions are completely web-based. Importantly for eCraft2Learn it is easy to add new blocks defined by small JavaScript programs. Snap4Arduino also has the ability to control an Arduino interactively and to generate a script that is compiled and run independently on the Arduino.

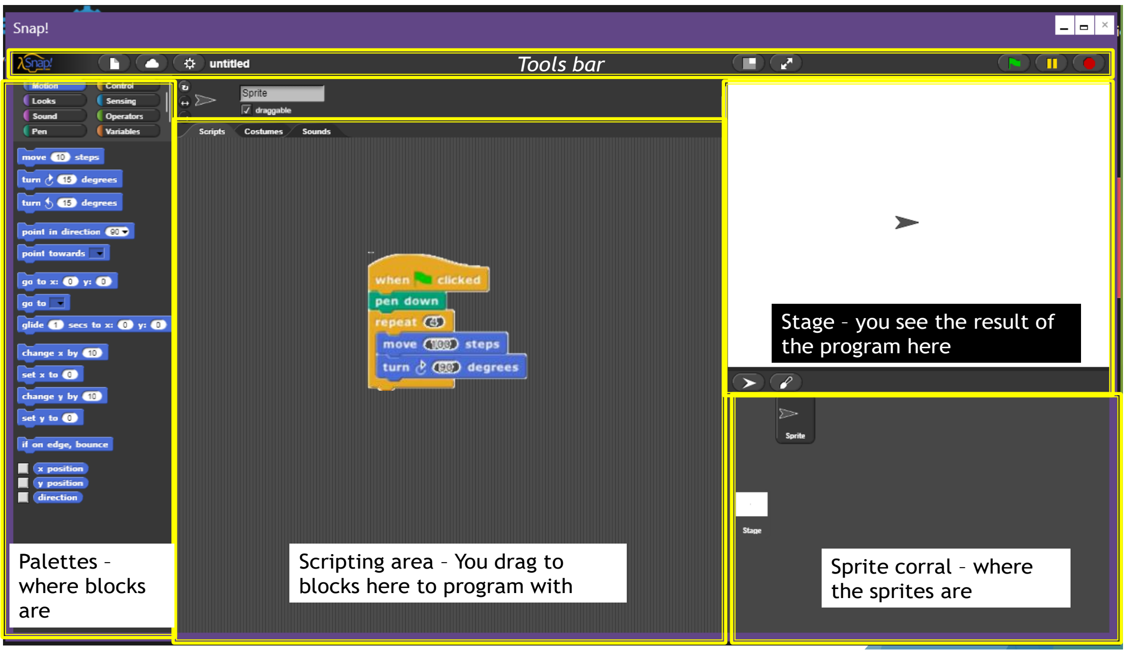


Figure 11. View of the Snap! programming environment accessible through the UUI

Like all blocks-based languages students using Snap! are presented with a semantically organised palettes of program components as differently shaped coloured blocks[3]. This alleviates the need to memorise many commands since they are easily available by browsing and then dragging into one's program. Syntax errors do not distract from the efforts of students since only syntactically correct combinations of blocks fit together like jigsaw pieces.

There are two very different kinds of activities that students can pursue using Snap4Arduino. In one the full power of a general purpose programming language running on the Raspberry Pi sends commands to the Arduino. Projects can have their artefacts move, light up, make sounds, and much more in response to either what is sensed within Snap4Arduino such as keyboard and mouse events, responses from Internet queries, or what any sensors connected to the Arduino report about light levels, touch, movement, and much more. For example, a robotic insect can be created that runs away from light and navigates around obstacles it bounces into. The other manner of using Snap4Arduino is much more limited but has the advantage that when the programming is complete the artefact can be made independent of any PC or Raspberry Pi. If the program is restricted to only those commands that can be translated to run on the Arduino then a light-avoiding insect robot, or burglar alarm, or lighthouse can be run with only an Arduino making the device smaller, lower energy consuming, cheaper, and more reliable.

3.5.2. A.I. Programming

Students can build artefacts that rely upon AI cloud services and machine learning. This enables them to build artefacts that respond to voice commands, generates speech, recognises images, and more. This has been accomplished by developing a library of new Snap! blocks that call upon services from Google, IBM, or Microsoft to do image recognition and speech synthesis and recognition. The new blocks were designed to include both easy-to-use simple blocks for these tasks as well as more complex blocks that expose most of the underlying functionality of AI cloud services. All this works in a web browser. With a good Internet connection it runs well even on relatively weak computers such Raspberry Pis since the hard work is being done in the cloud.

Recently the ability to augment AI cloud services with machine learning locally in the browser has become feasible. The development of *tensorflow.js* (formerly known as *deeplearn.js*) opens up the possibility of fast machine learning training and prediction in web-based programs. The eCraft2Learn Snap! A.I. blocks library now includes blocks for training the computer to recognise images (and soon also audio and other data). Students can use this for example to build programs where hand or body

[3] Snap! manual can be accessed through the OERs menu (https://ecraft2learn.github.io/uui) or through this link https://snap.berkeley.edu/SnapManual.pdf

gestures control how their artefacts move or behave. An artefact can also be trained to behave differently depending upon what is in front of its camera.

Several sample projects have been developed using the AI extensions to Snap!. One example is a robot (virtual or real) that responds to voice commands to move and turn. Another is device that listens for the name of a famous person or place and then speaks its description obtained by querying Wikipedia. A robot can send images from its camera to cloud services that respond with a description of what is in front of it and the robot can act differently depending upon what it sees. A vehicle can be constructed that has been trained to drive to the left or right depending upon whether the student in front of a camera is leaning left or right. It can be programmed to stop when it recognises an outstretched hand. Different coloured LEDs can be turned on or off by speaking the name of the colour. A box with a camera and speaker can be built so that when a leaf is placed inside it says what plant it is from (after the students have trained it to classify different leaves). A gadget with a camera can be trained to sound an alarm is someone falls down and fails to get up. ***The OERs and training material for students and teachers/coaches on A.I programming in Snap! and Snap4Arduino through the UUI are found in the Educational Resources – A.I. menu (https://ecraft2learn.github.io/uui).***

3.5.3. Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware (see Figure 12) and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online et cetera. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE) based on Processing.

Figure 12. Arduino Uno board

3.5.3.1. Why Arduino?

Thanks to its simple and accessible user experience, Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community[4].

3.5.3.2. How an Arduino Board Works?

Arduino boards are small computers with which you can read information from a variety of sensors as well as control lights, motors and other things. Many of the things around you are computers of different sizes. Computers do not need to have a keyboard or a screen. There are computers in the microwave oven in the kitchen, inside elevators to detect the buttons you press, in cars, etc. Arduino boards has a number of pins that are numbered and grouped by functionality. On the Arduino UNO, shown in the image above, group of 14 pins (numbered 0 to 13) that are the digital pins and yet another group of 6 pins (labelled A0 to A5) that are the analogue ones (see Figure 13).

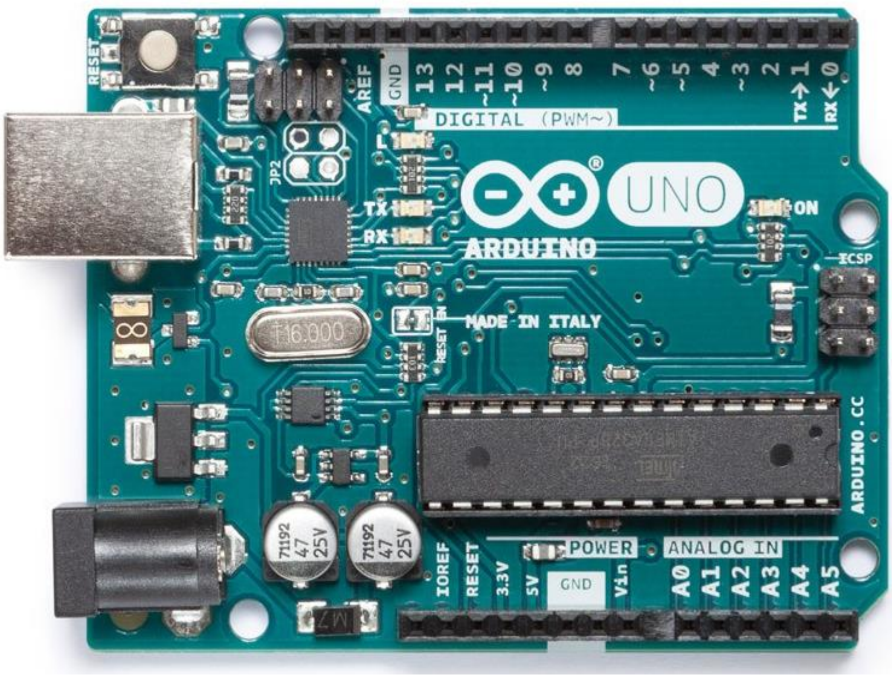
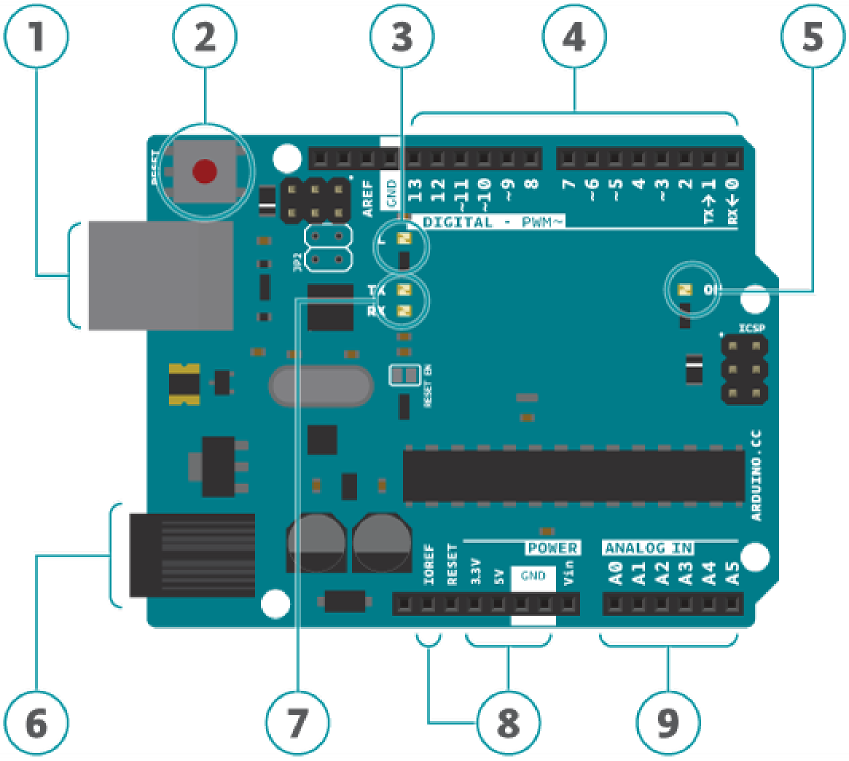


Figure 13. Arduino Uno board pins

[4] See further explanation on the selection of tools for the eCraft2Learn project in D4.2

3.5.3.3. Arduino Uno

Arduino UNO is the best board to get started with electronics and coding. If this is your first experience tinkering with the platform, the UNO is the most robust board you can start playing with. The UNO is the most used and documented board of the whole Arduino family. Read more about it here. To understand how the UNO board works, check out the illustration and descriptions below:



1) USB socket: When uploading a program to the UNO it is done through a USB cable. The USB cable is connected to a computer and to the USB socket. The cable also provides power to the UNO board.
2) Reset button: When the reset button is pressed, the program uploaded to the board is restarted.
3) On-board LED: This LED is connected to digital pin 13. You can turn the LED on or off by programming pin 13.
4) Digital pins: You can connect digital inputs and outputs to these pins. There are 14 digital pins, numbered from 0 to 13.
5) ON LED: This LED is turned on when the UNO is supplied with power.
6) Power socket: To provide the UNO board with power you can connect a battery or adapter to the power socket. The recommended input voltage is 7-12V.
7) TX and RX LED:s: The TX LED blinks when data is sent by the UNO over the serial port. The RX LED blinks when the UNO receives data over the serial port.
8) Power and ground pins: The power pins are marked IOREF, 3.3V and 5V. The ground pins are marked with GND.

9) Analogue pins: You can connect analogue sensors to these pins. There are six analogue pins numbered from A0 to A5.

3.5.3.4. Uploading Programs to the Boards

Since Arduino boards, unlike computers, does not have a screen or a keyboard, you need to use external software running on a different computer when writing programs for your control board. This software can be the text-based Arduino IDE (stands for "Integrated Development Environment") or visual programming environment of Snap4Arduino, accessible through the UUI[5]. In the eCraft2Learn project, it is recommended the use of Snap4Arduino to program the Arduino boards connected to the technical core or PC/laptop. The Arduino board can communicate with Snap4Arduino via the UUI by pressing the 'Connect Arduino' button from the Arduino palette (see Figure 14). Once the board is connected to Snap4Arduino, programs can be executed in the board.

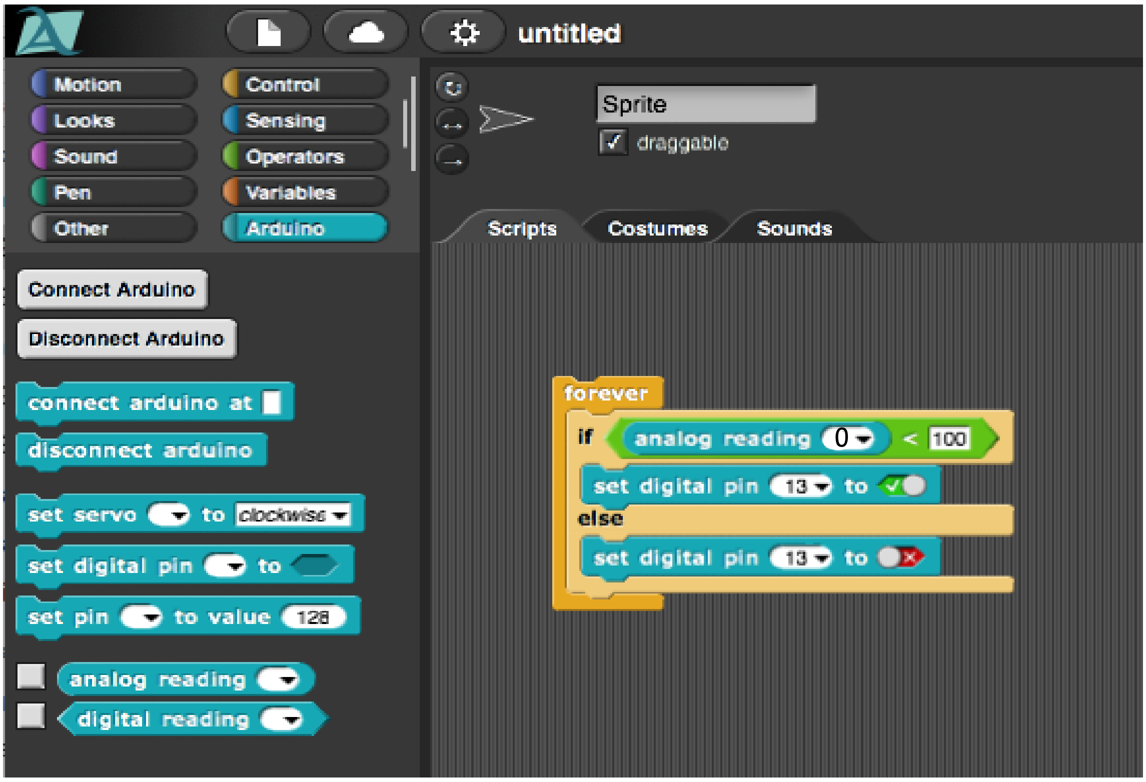


Figure 14. Snap4Arduino connection to Arduino board

[5] There is also an Arduino Web Editor that allows to write code and upload sketches to any official Arduino board from a web browser. This IDE is also text-based. The [Arduino Project Hub] contains a great variety of tutorials and projects for inspiration.

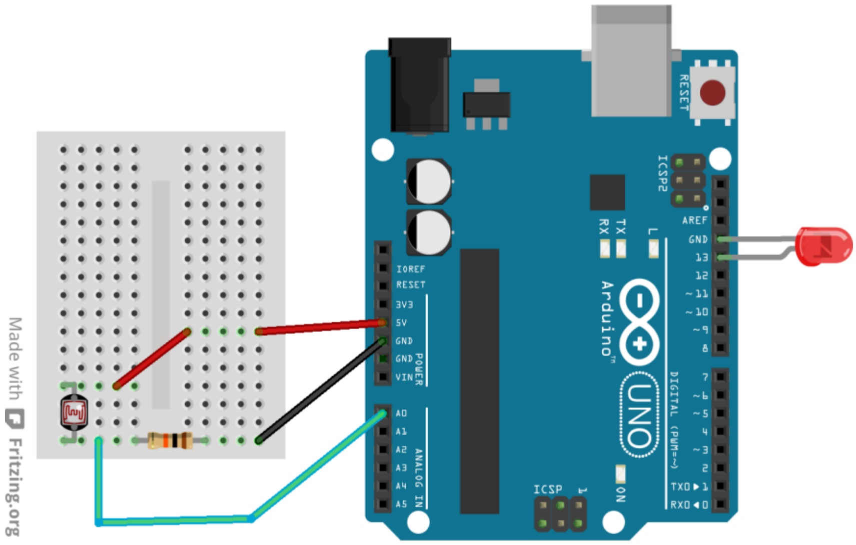


Figure 15. Analogue input reading - Photoresitor exercise

Hands-on practical exercise

This example shows you how to read analogue input from the physical world using a photoresisto A **photoresitor** is a light-controlled variable resistor. This means that the value of the resistance will change depending on the amount of light in the environment. By passing voltage through a photoresitor and into an analogue input on your Arduino board, it is possible to measure the amount of resistance produced by a photoresitor as an analogue value. In this example, you will monitor the state of your photoresistor after establishing serial communication between your Arduino and your computer via Snap4Arduino. According to the value of the photoresistor you will turn an LED (light emitting diode) on or off.

Hardware required

- Arduino Board
- Photoresistor
- Resistor (1K ohms) – *[this website is a good help to calculate resistors http://resistor.cherryjourney.pt/]*
- Hook-up wires
- Breadboard

Procedure

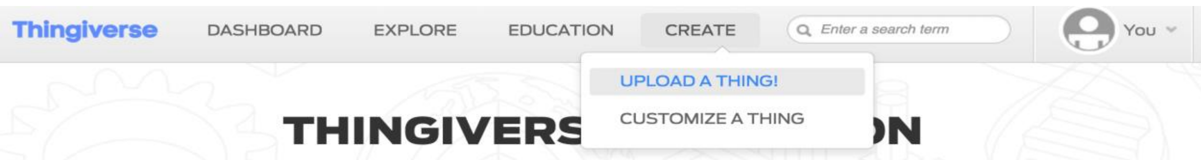
Connect the two pins from the photoresistor to your Arduino board through a breadboard using hook-up wires. One of the pins from the photoresistor goes to ground (GND) volts through a resistor and to analogue pin A0. The second goes to 5volts. You can connect your LED directly to the Arduino board or through the breadboard using hook-up wires. Connect the LED to GND and to digital pin 13. See Figure 15 for the connection of the circuit. After connecting your board to your PC/Laptop/RPi using Snap4Arduino, write the block code shown in Figure 14 and click on it to execute it on the board. You should see the LED blink depending on the amount of light in the environment (threshold set at 400 units measured by the photoresistor). Try changing this amount, covering the photoresistor with your hand, etc., to observe the behaviour.

3.6. Share Stage Tools

The Open Source community has created many online platform to share their work with the world. It started with simple discussion forums and upload on private servers, to be now on specialised websites offering dedicated pages for creator to present and give away their creations. One such websites is **Thingiverse**, dedicated to the sharing of 3D printing files. With over a million different shared project, this platform offers a great amount of inspiration for students, as well as an easy way to share their creation. The platform encourages people to publish under the Creative Common licence in order to allow everyone to take a project and modify it, making this a perfect platform for learning and sharing. Students also have the possibility to share directly from **TinkerCAD**, which offers similar functionalities than Thingiverse.

Thingiverse offers a very straightforward way of sharing documents. As usual for this kind of websites, an account is needed. A quick tutorial is offered after being registered to guide newcomers on the website and encourage them to be active socially. This, however, is not a requirement in order to use the website and upload creations. The ribbon below is taken from the Thingiverse website

If you create an account, once logged in, simply go to Create -> Upload a Thing! to share your creation, as shown below



By simple drag and drop or by uploading for the hard drive, a file can be uploaded (see Figure 16). It is important however to fill in the information about the file for others to be able to find it, understand its purpose, and use it. It is possible for teachers to upload a file that can be approved by for the Thingiverse moderators for Education part of the website. This is a great way to give awareness of a production and a good indication that these files are safe.

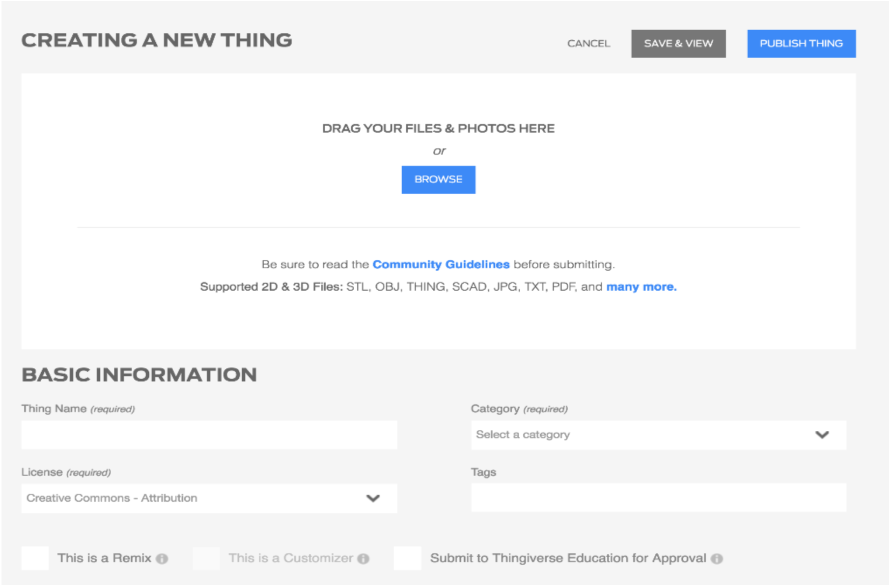


Figure 16. File upload interface of Thingiverse

It is encouraged to give as much information about the file (see Figure 17). For example, with a 3D printing file, settings of the printer itself is extremely important. If the file is part of a project, uploading a PDF file as well with instruction is very helpful to others. It is highly recommended for the Thingiverse for Education.

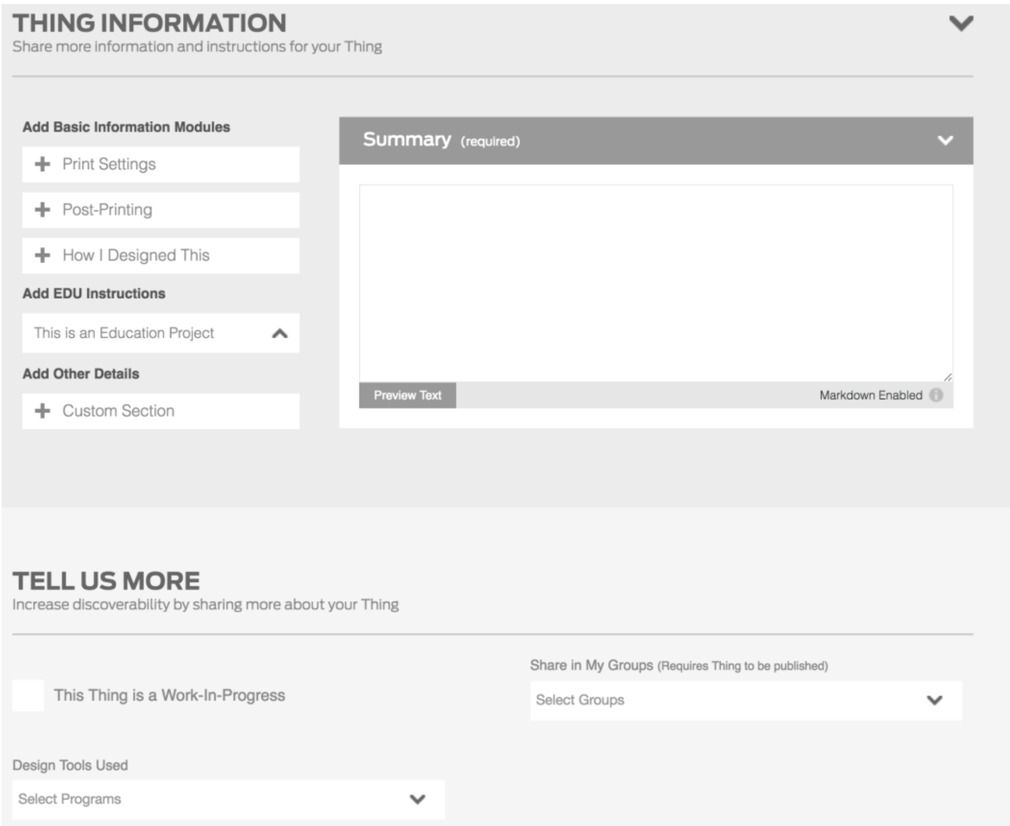


Figure 17. Data for the uploaded file in Thingiverse

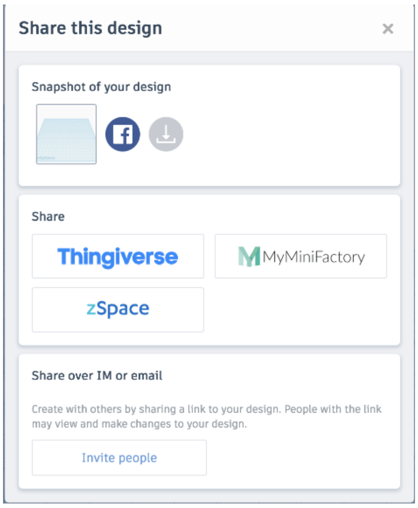


Figure 18. Share to Thingiverse from TinkerCAD

If students work on TinkerCAD, a link to share directly to Thingiverse is available under the Share option (see Figure 18). Several additional options are available on TinkerCAD, such a downloading the file, or share it on Facebook (2D snapshot only). TinkerCAD offers an easy way to share 3D models directly on three services: Thingiverse, MyMiniFactory, and zSpace. MyMiniFactory is a 3D printing file sharing website available in both English and French. One particularity of this platform is that every single file submitted will be tested on printers before being available to everyone. zSpace is a website specialised in visualising 3D models using AR and VR technology. Depending on the project, teachers and students can easily choose which platform is the most suitable for their needs.

Although Thigiverse provides a good outlet for sharing projects with the open community of practice, it is being recommended to create a native sharing tool for the eCraft2Learn digital platform based on the feedback from the 1st round of pilots (see D5.3).

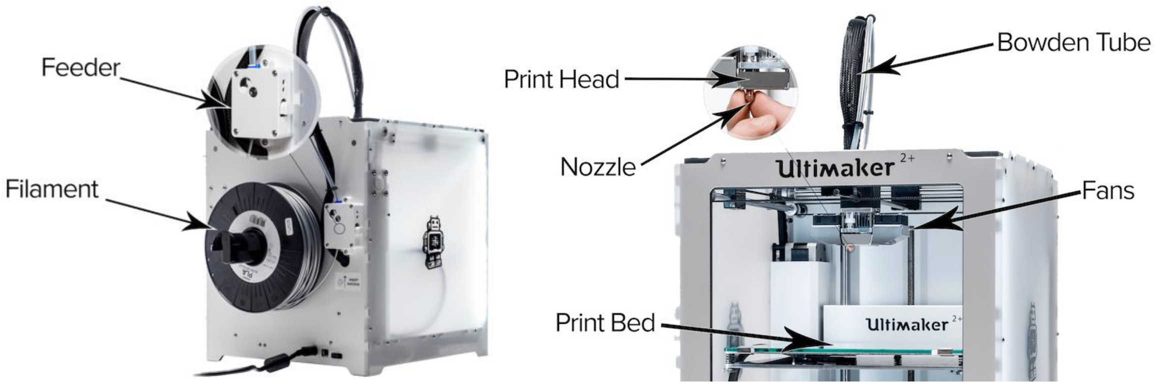
If versioning is very common for programming project with platform such as GitHub, the current sharing platforms for sharing 3D printing files and creation projects are quite limited. The project eCraft2Learn is planning to offer a sharing tool with the possibility to share ongoing projects and receive feedback at multiple stages of the activity. The feedback should be separated by levels, such as peers, teachers/supervisors, teammates, or community. The tool should not be limited to a certain type of file (e.g., not only 3D files, or programming file), but should allow the teacher/student to share their work on all the stages of their progress while working in the UUI. Each stage should be able to receive feedback. This native tool is currently under development and should address the previous requirements and to complement the Thingiverse sharing functionalities.

3.7. 3D Printing

The addition of 3D printing in the eCraft2Learn ecosystem allows students to design and manufacture components to complement their DIY electronics. Examples include casings for the Arduino, housing units for the electronic components and structural or moving parts e.g. robotic arms, vehicle chassis, wheels, gears etc. In this section, guides and tutorials for understanding, setting and working with 3D printers (Ultimaker) are put forward.

3.7.1. How 3D Printers Work

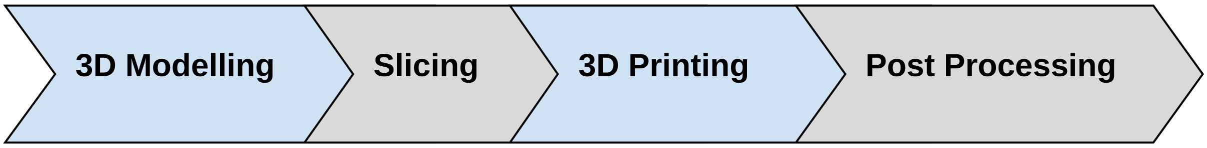
The 3D printers most commonly used in schools, including the Ultimaker 2+ and the Ultimaker 3 are desktop FDM (Fused deposition Modelling) printers. They use a thermoplastic "filament" which is supplied on rolls. The most common filament used in schools (and the one recommended for craft projects) is called PLA (poly lactose acid). This biodegradable material is derived from cornstarch and has a number of benefits; it is low cost, the fumes are less harmful than other plastic filaments, is safer for school environments and it is a very easy material to 3D print with, producing consistently good results.



The filament is passed through a feeder motor (located on the rear of the Ultimakers) which pushes it through a "bowden tube" into the "hot end". Here the material is heated (approx. 210°C for PLA). The molten filament is then pushed through a very fine nozzle onto a print bed. The nozzle moves around the print bed laying down a very fine layer of material, when the first layer has been printed, the print bed moves down a fraction and the next layer is printed on top. Fans at either side of the print head blow cold air over the print surface to cool it and, as the layers of material cool, they fuse together. The layers are built up to create a 3-dimensional shape.

3.7.2. 3D Printing Process

The 3D printing process consists of a number of stages from initial design to production of a 3D printed object.



The eCraft2Learn UUI provides links to a number of tools to facilitate this process. **TinkerCAD** is the recommended 3D modelling tool, whilst Beetleblocks allows 3D models to be generated from code. **Cura** is the recommended slicing software for use with Ultimaker 3D printers.

The following eCraft2Learn resource provides more detailed information about how 3D printing works and the 3D printing process ***Introduction to 3D printing*** available through the Educational Resources – 3D Printing menu of the UUI.

3.7.3. Activity – Setting up the 3D Printer

Before you can start 3D printing, the printer must be set up. This consists of the following stages:

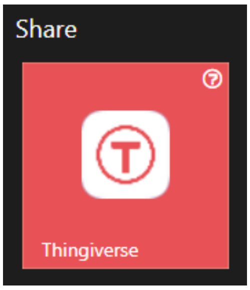
1. Unboxing
2. Installation - Insert the spool holder, insert the glass plate and connect the power.
3. Bed levelling (also known as calibration)
4. Inserting (or replacing) the filament.

Work through the above steps using the Ultimaker 2+ or the Ultimaker 3 User manuals in the UUI to guide you through each process. Now the printer will be ready to print.

<u>Activity - Your first 3D print</u>

Once the 3D printer has been set up try printing the Ultimaker robot model. This makes a very nice first print and shows some of the the fine details that can be achieved with a 3D printer.

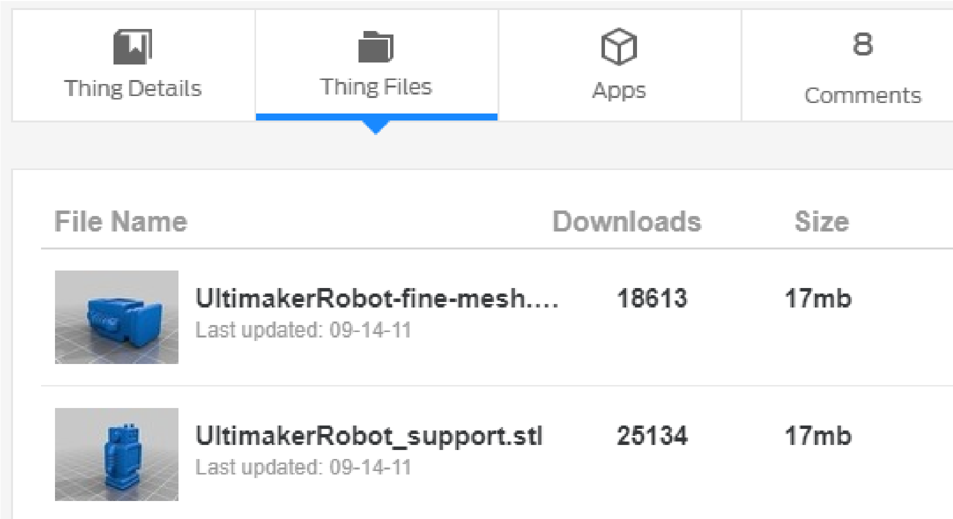
1. In the UUI “Share” area, click on the large Thingiverse tile. This will open up Thingiverse, a 3D model sharing site.



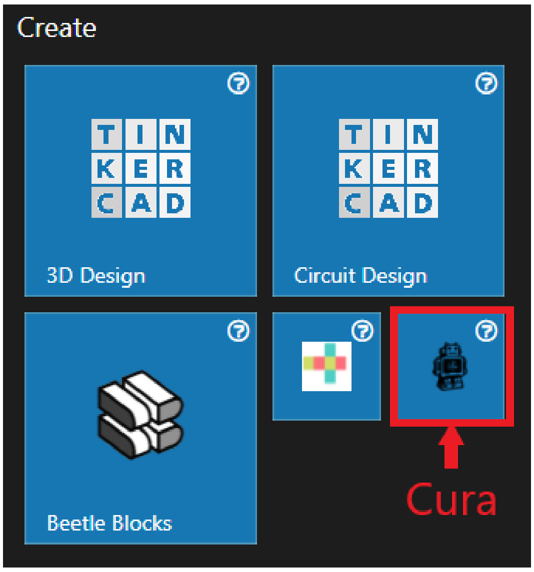
2. Type “Ultimaker Robot” into the search bar in the top menu.

3. Select the first result by “Martijn”

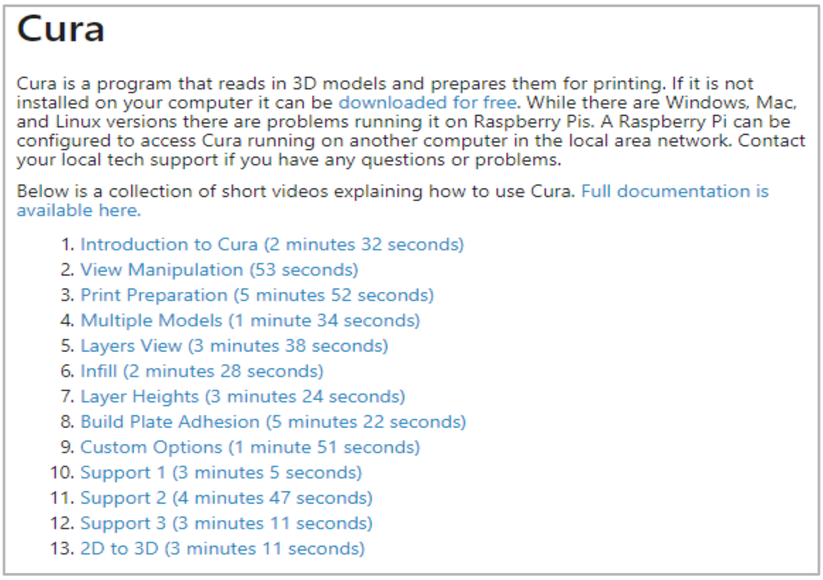
4. Click on the “Thing Files” tab and select the “UltimakerRobot_support.stl” file to download it.



5. In the UUI “Create” area, click on the small “Cura” tile. Click on the link in the information window to download and install the Cura slicing software.



6. Watch the 13 short Cura tutorial videos to learn about the software and how to slice your models.



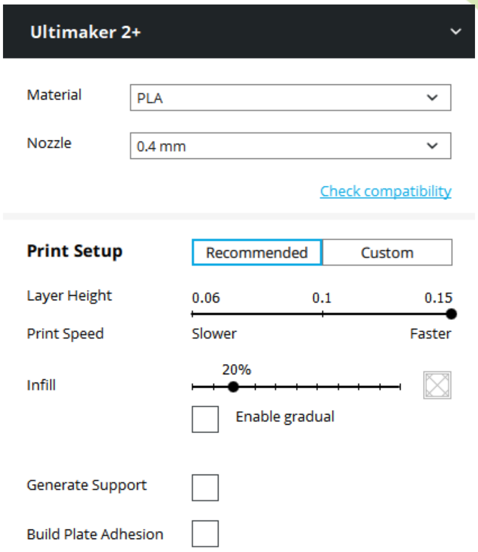
Cura

Cura is a program that reads in 3D models and prepares them for printing. If it is not installed on your computer it can be downloaded for free. While there are Windows, Mac, and Linux versions there are problems running it on Raspberry Pis. A Raspberry Pi can be configured to access Cura running on another computer in the local area network. Contact your local tech support if you have any questions or problems.

Below is a collection of short videos explaining how to use Cura. Full documentation is available here.

1. Introduction to Cura (2 minutes 32 seconds)
2. View Manipulation (53 seconds)
3. Print Preparation (5 minutes 52 seconds)
4. Multiple Models (1 minute 34 seconds)
5. Layers View (3 minutes 38 seconds)
6. Infill (2 minutes 28 seconds)
7. Layer Heights (3 minutes 24 seconds)
8. Build Plate Adhesion (5 minutes 22 seconds)
9. Custom Options (1 minute 51 seconds)
10. Support 1 (3 minutes 5 seconds)
11. Support 2 (4 minutes 47 seconds)
12. Support 3 (3 minutes 11 seconds)
13. 2D to 3D (3 minutes 11 seconds)

7. Open the saved Robot STL file in Cura, slice it using the following print settings:



8. Save the file to an SD card for printing on the Ultimaker 2+ or a USB for printing on the Ultimaker 3.
9. Insert the SD card or USB into the printer, Use the push/rotate button on the front of the printer to select Print, then select your file. this will start the 3D print.

Always watch (or keep checking) the first layer being printed if possible, If a print is likely to fail, it is usually due to a problem that occurs when printing the first layer.

When the print has finished, wait until the print bed cools down before removing the print.

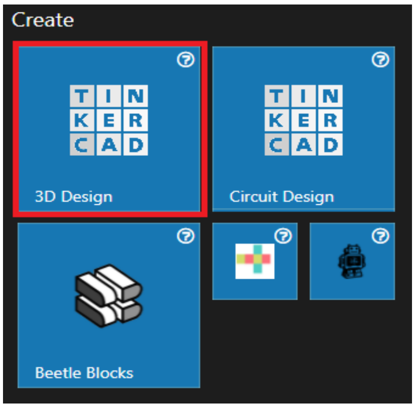
3.7.4. 3D Modelling with TinkerCAD

TinkerCAD is a straightforward 3D CAD program to learn to use, the software has a simple interface and is based around building up a design by using 3D shapes from the library and combining them (by adding or subtracting shapes) to build your model. TinkerCAD is web based and can be accessed through the UUI. The easiest way to learn TinkerCAD is to visit the “Learn” section on the TinkerCAD website. This area contains lots of of tutorials and step-by-step design projects. You can work your way through these in your own time to learn the software basics and develop your CAD skills. The tutorials are visible on-screen alongside the TinkerCAD design interface making it very easy to follow them. At the end of each tutorial you will have mastered new skills as well as having a completed 3D model. This approach could also be used with the students so that they can master the basics of TinkerCAD.

Activity - Produce a 3D model from a TinkerCAD tutorial

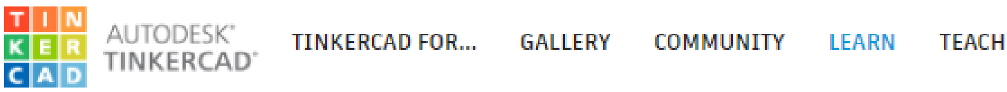
In this activity, you will follow a series of TinkerCAD lessons then a tutorial to produce produce a CAD model that can be 3D printed.

1. In the UUI "Create" area, click on the large TinkerCAD 3D Design tile. This will open up TinkerCAD, 3D modelling software.

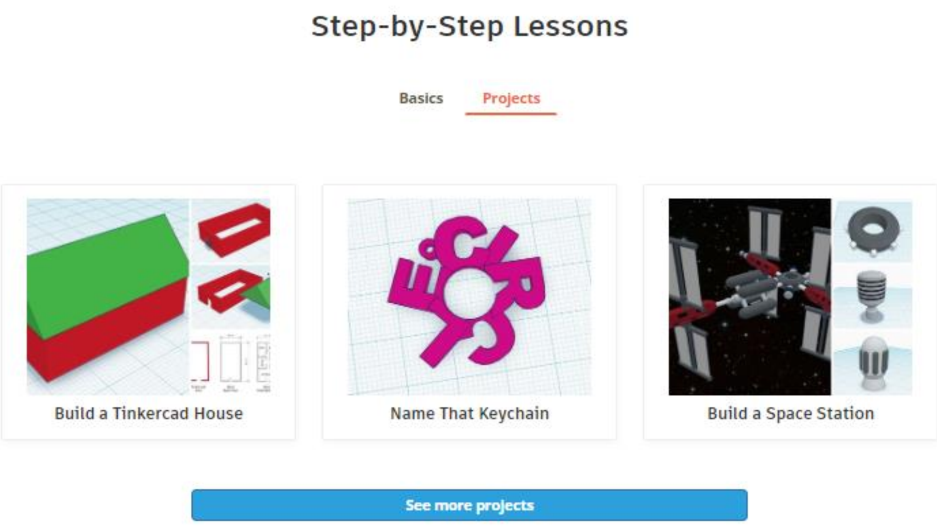


2. In the top left of the TinkerCAD menu, Sign up for a TinkerCAD account or Sign in if you have one already.

3. Click on "Learn" in the TinkerCAD top menu.

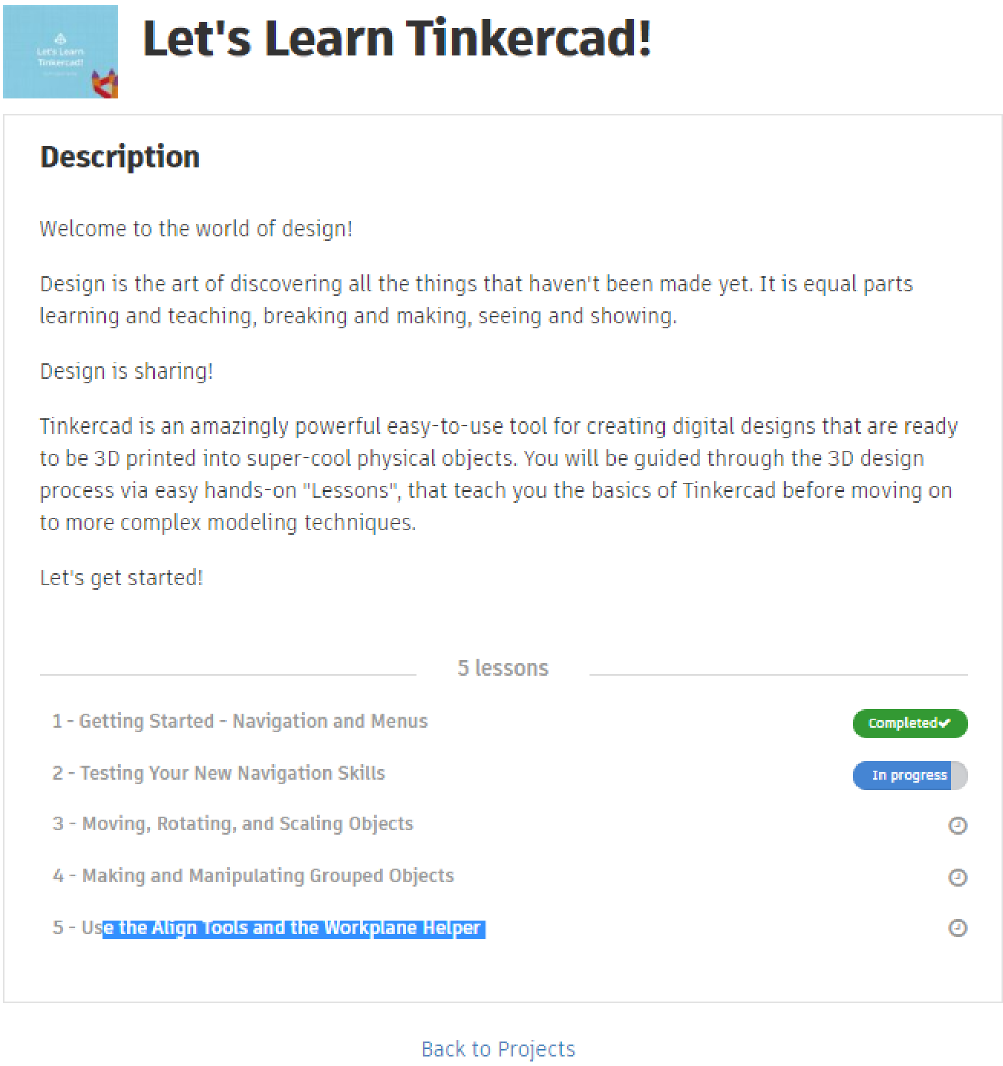


4. Select "Projects" then the blue "See more projects" button.



5. On the projects page, select the “Let’s Learn TinkerCAD!” project on the top row.

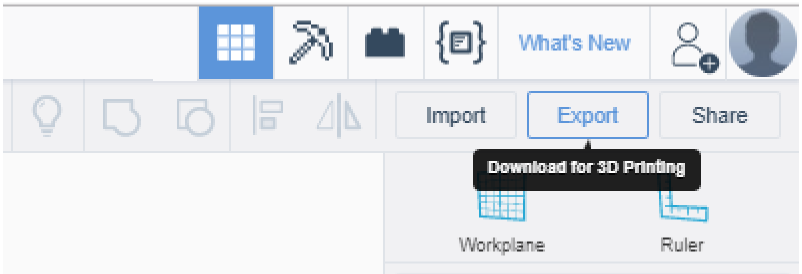
6. This will launch a series of 5 lessons to guide you through the TinkerCAD software. You can work your way through these lessons at your own pace. You can exit this at any time and the lessons record your progress, this will allow you to continue where you left off from when you log back into TinkerCAD.



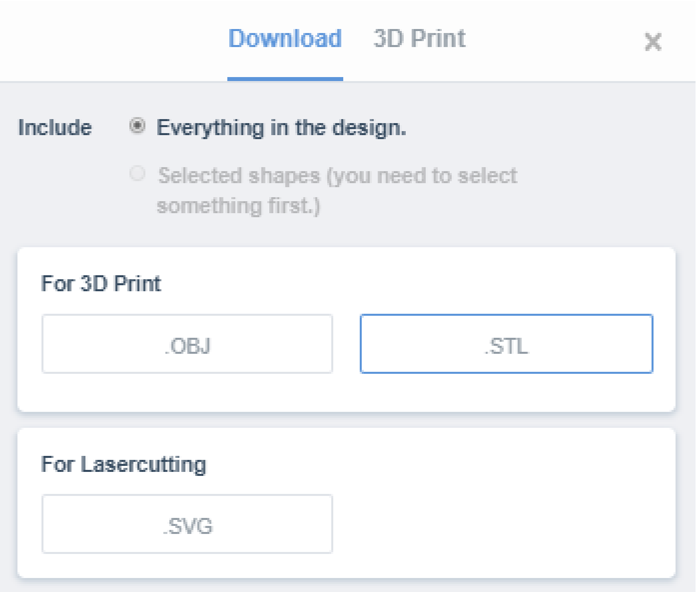
Complete the five TinkerCAD lessons.

7. Return to the projects list, scroll down the list of projects and select the "Chess Pawn" project, this is a good example project that allows you to practice and consolidate your TinkerCAD skills.

8. Complete the Chess Pawn project to produce a 3D model of a chess pawn. TinkerCAD auto saves your progress and your 3D model as you work. When you have completed your 3D model, click the "Export" button in the top right corner of the design interface.



In the pop-up, select ".STL".



This will download the 3D model as a .STL file that you can open in Cura.

9. Open your Chess Piece .STL in Cura, slice it, save it and 3D print it by following steps 7-9 of the "Your first 3D print" activity.

3.7.5. 3D Modelling with Beetle Blocks

Beetle Blocks is a graphical blocks-based programming application, based on Scratch. Beetle Blocks is web based and can be accessed through the UUI. Like Scratch, students can set up an account on the Beetle Blocks website where they can save their programs, access and remix others. For teachers and students familiar with Scratch it is very quick to learn the basics. The interface is very similar to Scratch, many of the programming blocks are the same and have the same functionality.

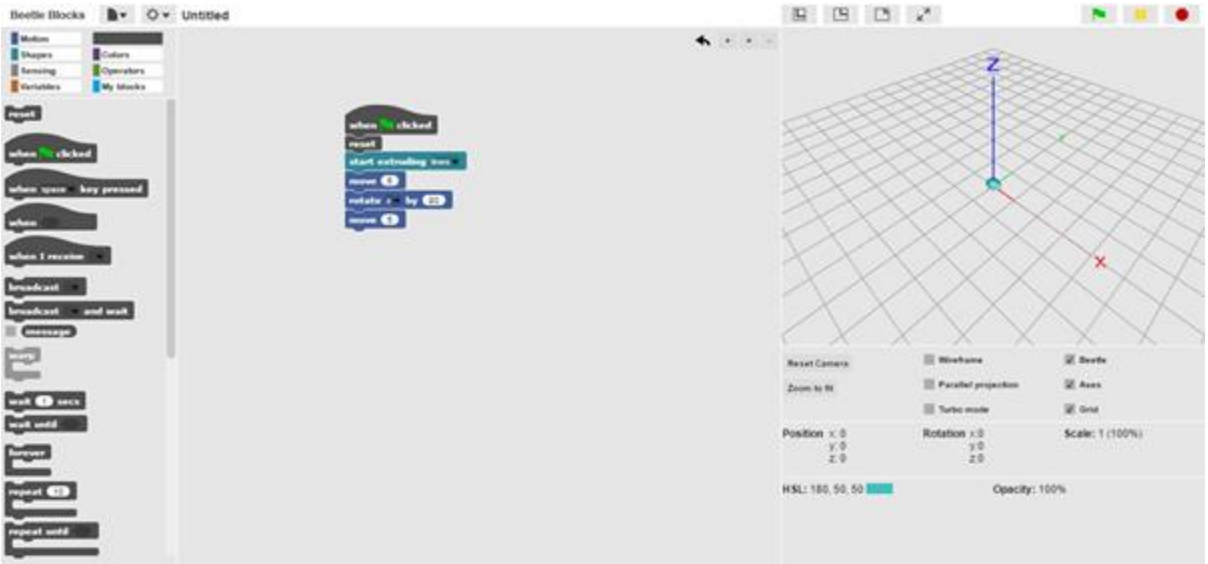


Figure 19. Beetle Blocks programming interface

The left part of the interface contains the programming blocks (see Figure 19), these are simply dragged into the coding area in the centre of the interface and stacked together. When the program is run, the beetle, which is shown in the X,Y,Z plane on the right of the interface responds to the code. The following documentation is currently available to help you to get started with Beetle Blocks:

- Beetle Blocks Primer: http://beetleblocks.com/static/bb-primer.pdf
- Beetle Blocks Getting Started Guide: http://forum.beetleblocks.com/t/getting-started-guide/119

The code blocks that are used for coding 3D printable designs are found in the “Shapes” menu (see Figure 20). The cube, cuboid, sphere and tube blocks will create these shapes with the specified dimension values. The text block will create text with the specified dimension. The start extruding block will allow you to extrude either a line or a curve along a path at any point in the program. The stop extruding block will stop the extrusion at any point in the program. The set extrusion diameter and change extrusion diameter blocks will allow you to change the diameter of the extrusion at any point in the program.

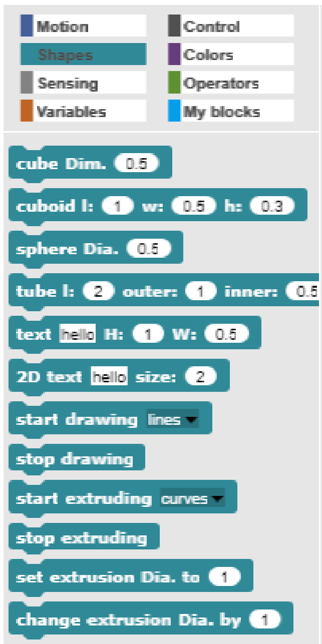
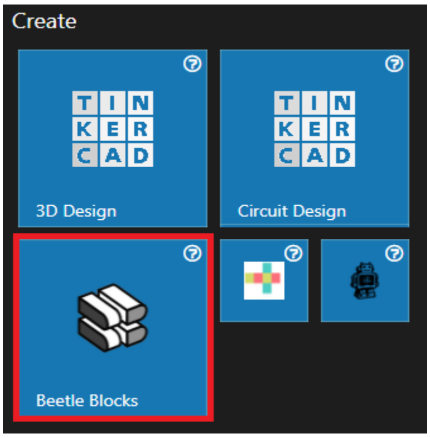


Figure 20. Beetle Blocs code blocks for 3D printing

Activity - Produce a 3D model from Beetle Blocks

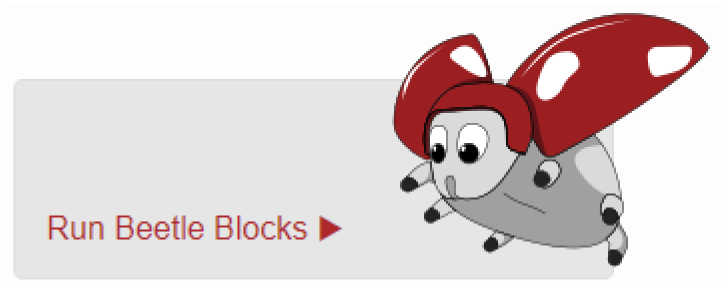
In this activity, you will create some code in Beetle Blocks that will extrude a shape, then export it as a CAD model file that can be 3D printed.

1. In the UUI "Create" area, click on the large Beetle Blocks tile. This will open up Beetle Blocks software.

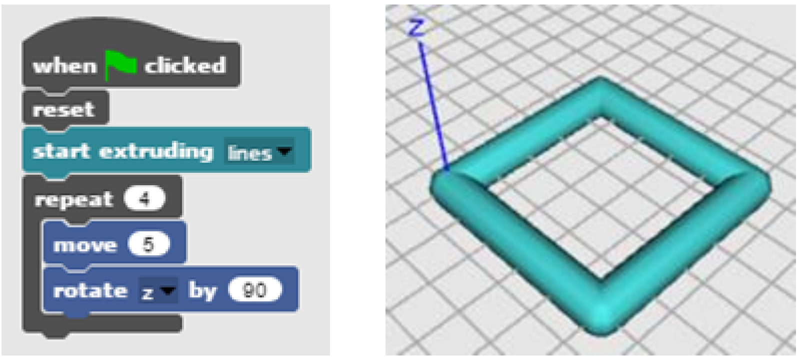


2. In the top left of the Beetle Blocks menu, Select Join Beetle Blocks to create a Beetle Blocks account or Log in if you have one already.

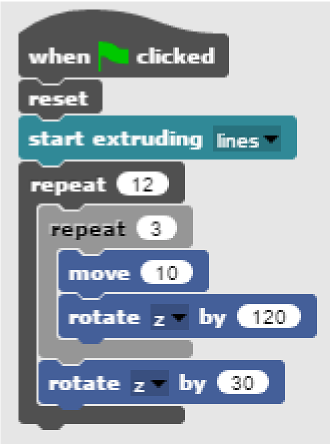
3. Click on "Run Beetle Blocks" just under the top menu.

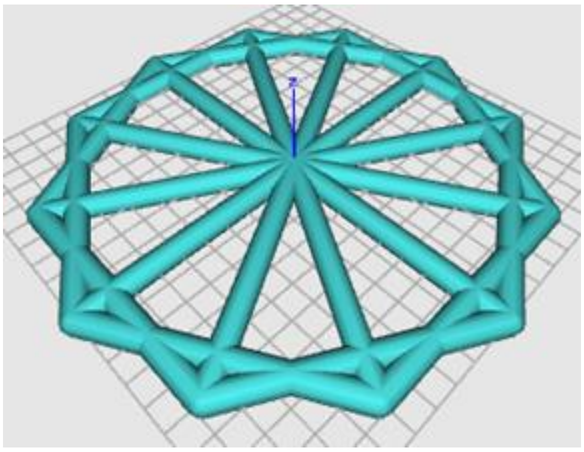


4. Create some code to extrude a simple shape, here is an example of the code to generate a square. Perhaps try to generate a triangle, hexagon or circle.



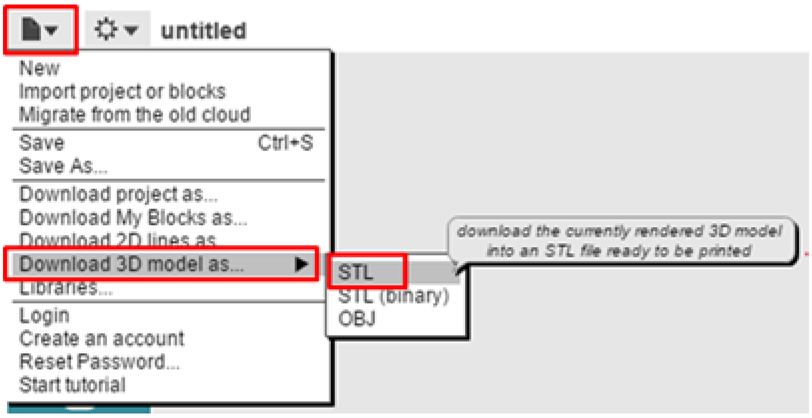
5. Now try to repeat the shapes to produce a more intricate design, here is an example.



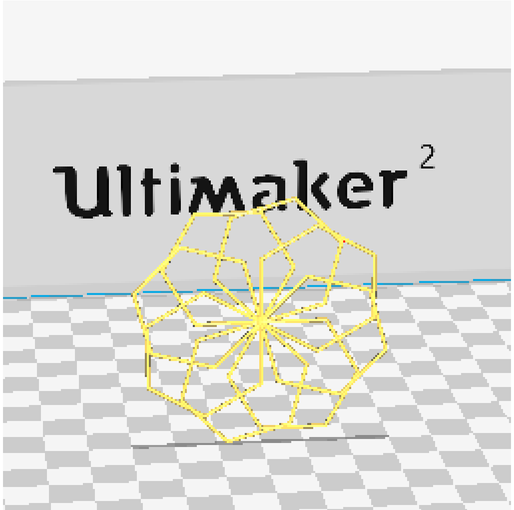


6. When you have a design you would like to print, save your file by selecting the folder icon above the coding blocks area then select “Save As”.

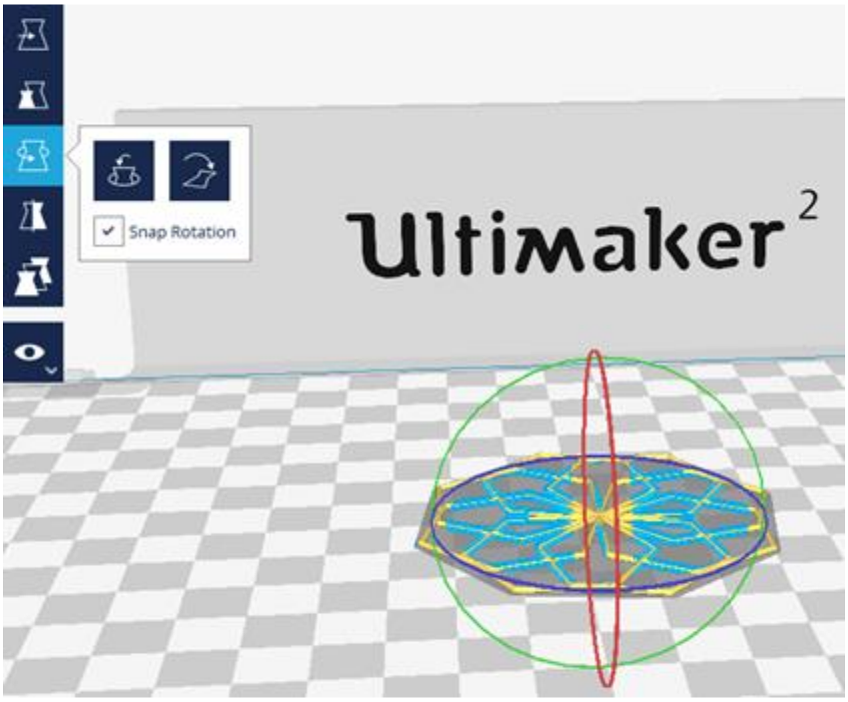
7. The saved file can then be exported, select the folder icon again, then select “Download 3D model as” a .STL file. By default each download will be named beetleblocks_export.stl. It is recommended that you should rename the download file to something more meaningful.



8. Open your Beetle Blocks .STL in Cura, however the flat designs always open on end as shown.



The design can not be printed this way, so students will need to rotate the object so that it lays flat on the build plate. First click on the model, then select the Rotate icon in the left menu, then click and drag on the red rotate node around the model and drag this down to 90°. This will lay the shape flat on the print bed.

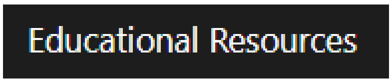


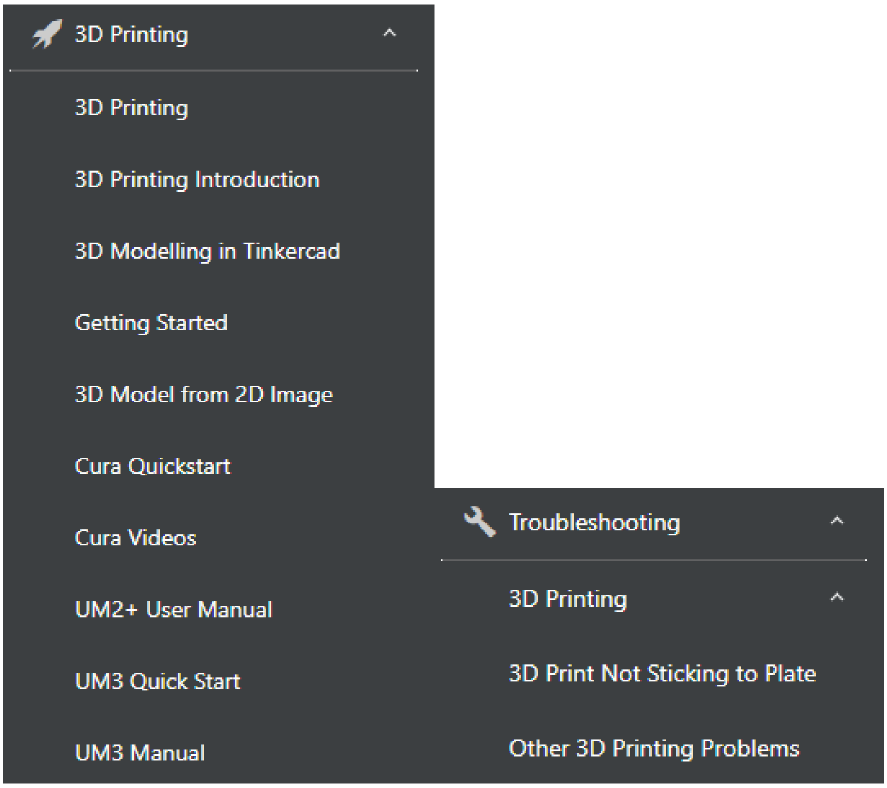
9. Slice the model, save it and 3D print it.

3.7.6. Common 3D Printing Problems/Troubleshooting

Common 3D printing problems include the print not sticking to the build plate, warping of the print and problems due an incorrectly calibrated build plate or blocked nozzle. Most of these problems are relatively easy to fix yourself and Ultimaker provide very comprehensive troubleshooting information and video help. The UUI contains 3D printer getting started guides, user manuals, help, dummies guides and troubleshooting information.

Click on the Educational Resources Link in the top right of the interface to access these resources.





If you have a specific problem that you cannot find an immediate solution to within the resources provided in the UUI, Ultimaker also have very knowledgeable and responsive User Community. Posting a question on the Ultimaker Community Forums usually receives multiple responses within hours. The community can be reached through the OERs – Community menu or through this direct link Ultimaker Forum: https://community.ultimaker.com/

3.8. Learning Analytics in Practice

The learning analytics teachers' interface is located in the following URL: https://ecraft2learn.github.io/learning-analytics/.

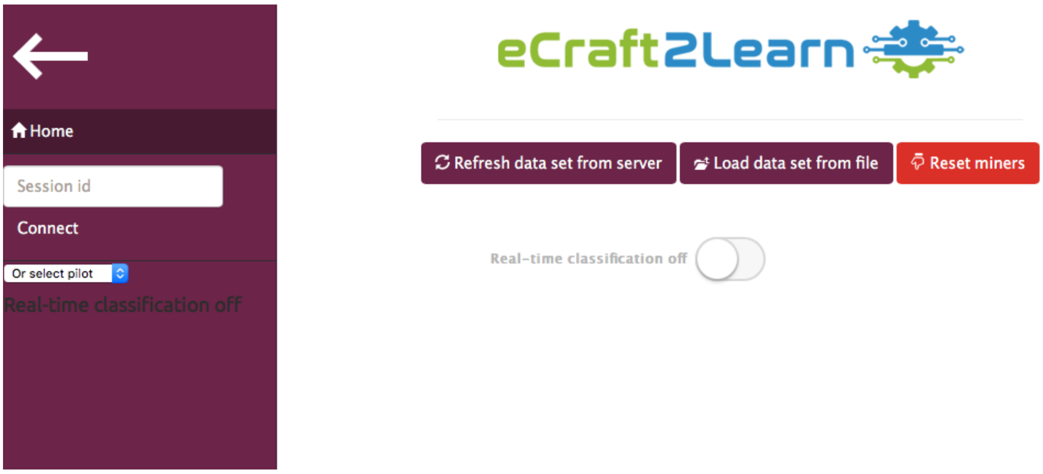


Figure 21. Learning analytics index page

When the teacher loads the website the view in Figure 21 is shown to teachers. From the side menu, the teacher is able to select the session the teacher wants to connect to. The name of the session can be written to the text field or it can be selected from the dropdown menu. The drop-down menu contains the sessions for each pilot. After the teacher has selected the session, the system automatically connects to the selected session and loads the dataset from the UUI for that particular session. Next, the rest of the user interface of the analytics is shown to the teacher. The next view is shown in Figure 22.

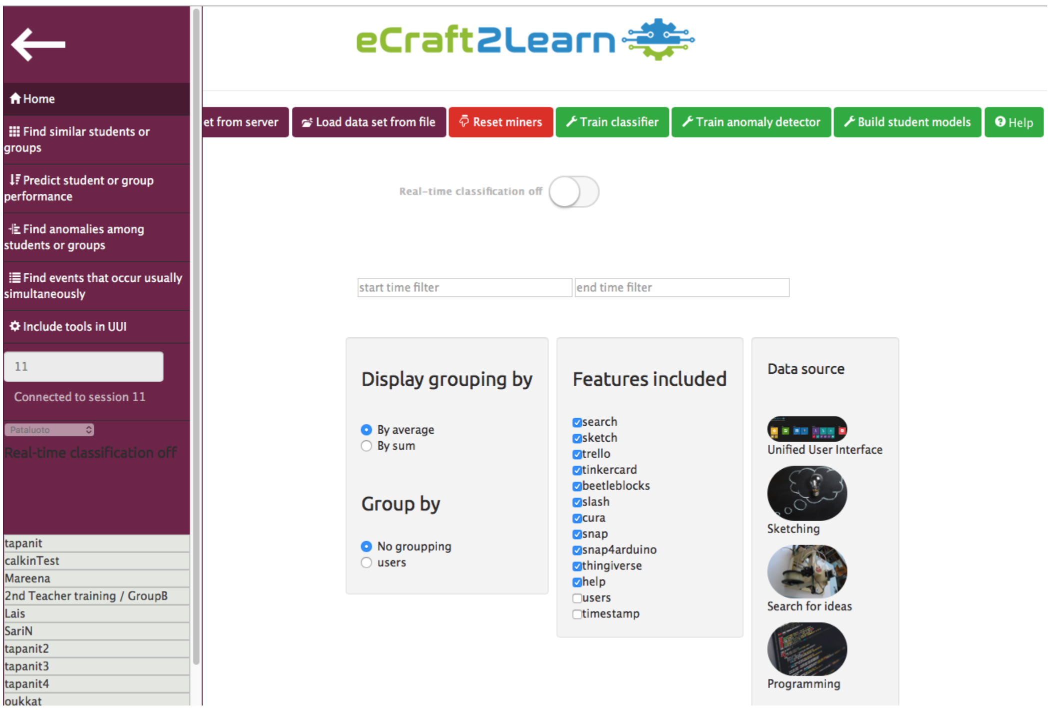
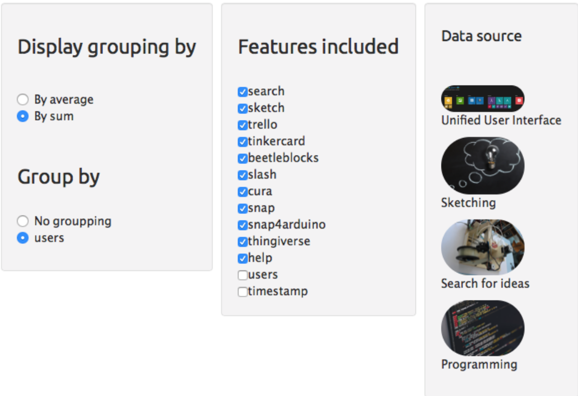


Figure 22. Learning analytics after connecting to a session

From this view, the teacher is able to view the students who are participating to the session. Also the teacher is able to perform all kinds of methods to edit the loaded dataset. For instance, the teacher is able to group the dataset item by the user, which means that because the UUI and its tools are recording individual actions and events, the teacher is able to view all events done by an individual student or a group of students. In addition, the teacher is able to select the data source for analysis, as each of the tools in the UUI can be viewed as a standalone tool in the context of the learning analytics.

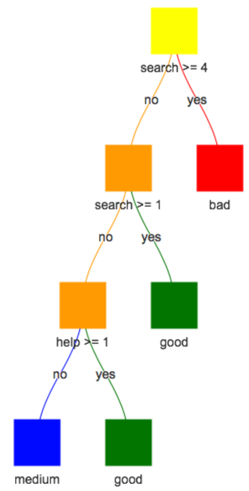
Figure 23 shows the display of the options that appear for selected dataset including the data entry points.



beetleblocks	slash	cura	snap	snap4arduino	thingiverse	help	users	timestamp	Predict	Anomaly
0	0	0	2	10	2	2	tapanit	10:31 PM	Not included	Not an anomaly
1	0	0	0	2	3	10	calkinTest	10:31 PM	Not included	Not an anomaly
0	0	0	0	2	0	1	Mareena	10:31 PM	Not included	Not an anomaly
0	0	0	0	1	0	0	2nd Teacher training / GroupB	10:31 PM	Not included	Not an anomaly
0	0	0	0	0	0	0	Lais	10:31 PM	Not included	Not an anomaly
0	0	0	0	0	0	1	SariN	10:31 PM	Not included	Not an anomaly
0	0	0	0	0	0	0	tapanit2	10:55 AM	Not included	Not an anomaly
0	0	0	0	15	0	0	tapanit3	12:09 PM	Not included	Not an anomaly

Figure 23. A dataset view of learning analytics

Each cell of the table in Figure 23 represents actions of the users (student or a group of students). From the table, the teacher is able to monitor which of the students are performing well, average or not so well. Or the teacher can select students for exclusion from the analysis. After making the decisions, the teacher can select any analysis tool the teacher wishes from the side menu. The tools consist of a *classifier*, *cluster analysis* tool, *anomaly detecto*r and *association rule learning* tool. If the teacher chooses to predict the student performance, the teacher will see the view as in Figure 24.



search	sketch	trello	tinkercard	beetleblocks	slash	cura	snap	snap4arduino	thingiverse	help	users
4	3	0	0	0	0	0	2	10	2	2	tapanit
5	3	0	1	1	0	0	0	2	3	10	calkinTest
5	1	0	0	0	0	0	0	2	0	1	Mareena

Figure 24. Decision tree of learning analytics

The decision tree classifier is rendered based on the labels that the teacher assigned to the students (performing well, not performing well, neutral performance and so on). From the rendered tree, the teacher can see how the data flows in the classifier. The table in Figure 24 also shows the students grouped according with coloured performance labels. **Red** means that the student is not performing well; **orange** means the student's performance is average and the **green** label means that the student is performing well. As it is expected, when the data flows automatically from the server, the new instances of the data are also labelled and thus the decision tree helps predict whether the students are currently performing well or not.

If the teacher selects the cluster analysis tool, the following view is shown to the teacher (Figure 25). A tree is again rendered for the teacher; each of the leaf nodes represent a cluster. In Figure 25 the clusters are 0, 1, 3 and 4. N = 12 tells that the cluster 3 has 12 students in it. If the teacher clicks the node, then the teacher is able to see which of the students belong to that cluster and why; the students will traverse the tree based on the values of the nodes.

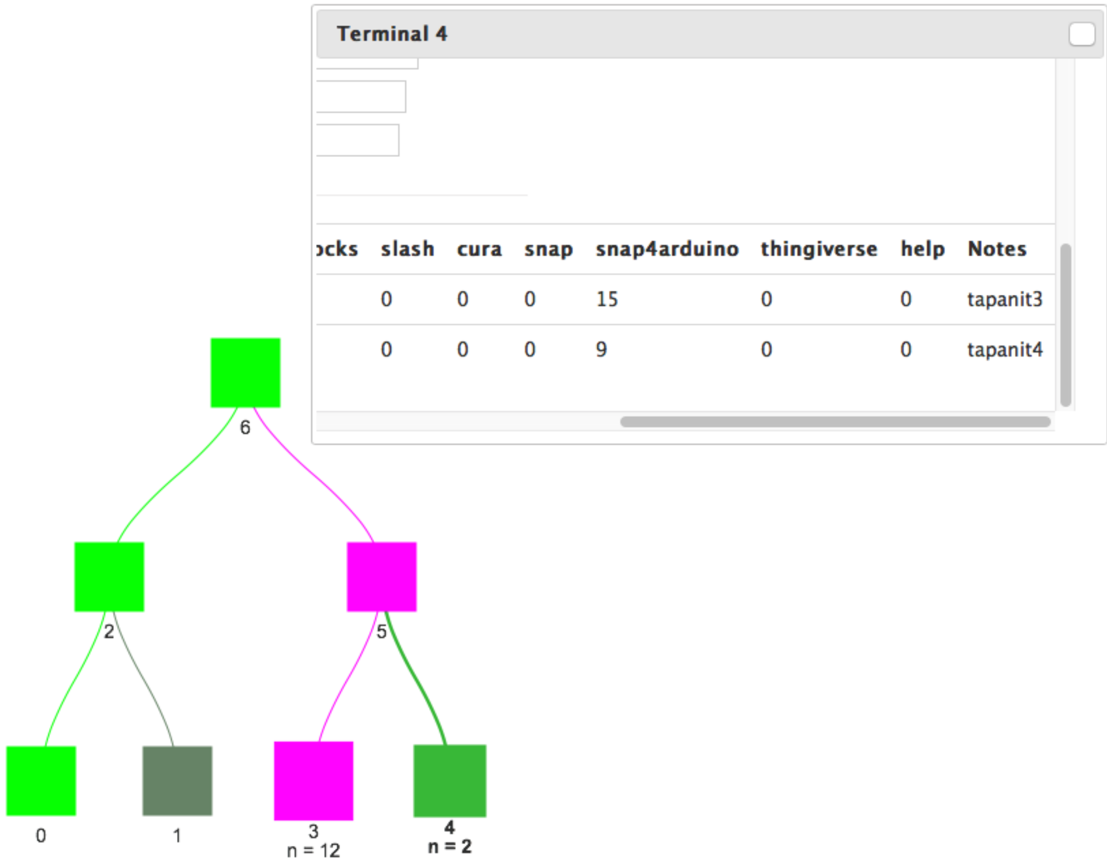


Figure 25. Cluster analysis tool of learning analytics

More similar clusters are in fact the siblings and so on. Therefore, we can tell from the pictures that even though there are only two clusters with data, the clusters are very similar to each other.

From the anomaly detection view, the teacher is shown a table as presented in Figure 26.

search	sketch	trello	tinkercard	beetleblocks	slash	cura	snap	snap4arduino	thingiverse	help	users	timestamp
4	3	0	0	0	0	0	2	10	2	2	tapanit	10:31 PM
5	3	0	1	1	0	0	0	2	3	10	calkinTest	10:31 PM
5	1	0	0	0	0	0	0	2	0	1	Mareena	10:31 PM
1	0	0	0	0	0	0	0	1	0	0	2nd Teacher training / GroupB	10:31 PM
0	1	0	0	0	0	0	0	0	0	0	Lais	10:31 PM
0	0	0	0	0	0	0	0	0	0	1	SariN	10:31 PM
1	0	0	0	0	0	0	0	0	0	0	tapanit2	10:55 AM
0	0	0	0	0	0	0	0	15	0	0	tapanit3	12:09 PM
0	0	0	0	0	0	0	0	9	0	0	tapanit4	1:19 PM
3	0	0	0	0	0	0	0	1	0	1	oukkat	4:30 PM
0	0	0	1	0	0	0	0	0	0	0	aaro	4:50 PM
0	0	0	0	0	0	0	0	5	0	0	Oukkat	4:57 PM
0	0	0	0	0	0	0	0	1	0	1	jetix	5:28 PM
0	0	0	1	1	0	0	0	0	0	1	afsheenam	9:39 PM

Figure 26. Anomaly detection of learning analytics

In the table of Figure 26, the students that fall under the 'anomaly' class are shown in red and the regular students are shown in green. Again, when the data flows from the server, the new instances of the student data are labelled with either red (anomaly) or green (non-anomaly), based on the type of activities that the students have perform while interacting with the UUI.

The **association rule learning** allows the teachers to view which events usually are linked together. For instance, if many students who regularly launch a certain tool from UUI and additionally launch a help tool also, this will be shown to teacher in the form a directed graph as shown in Figure 27.

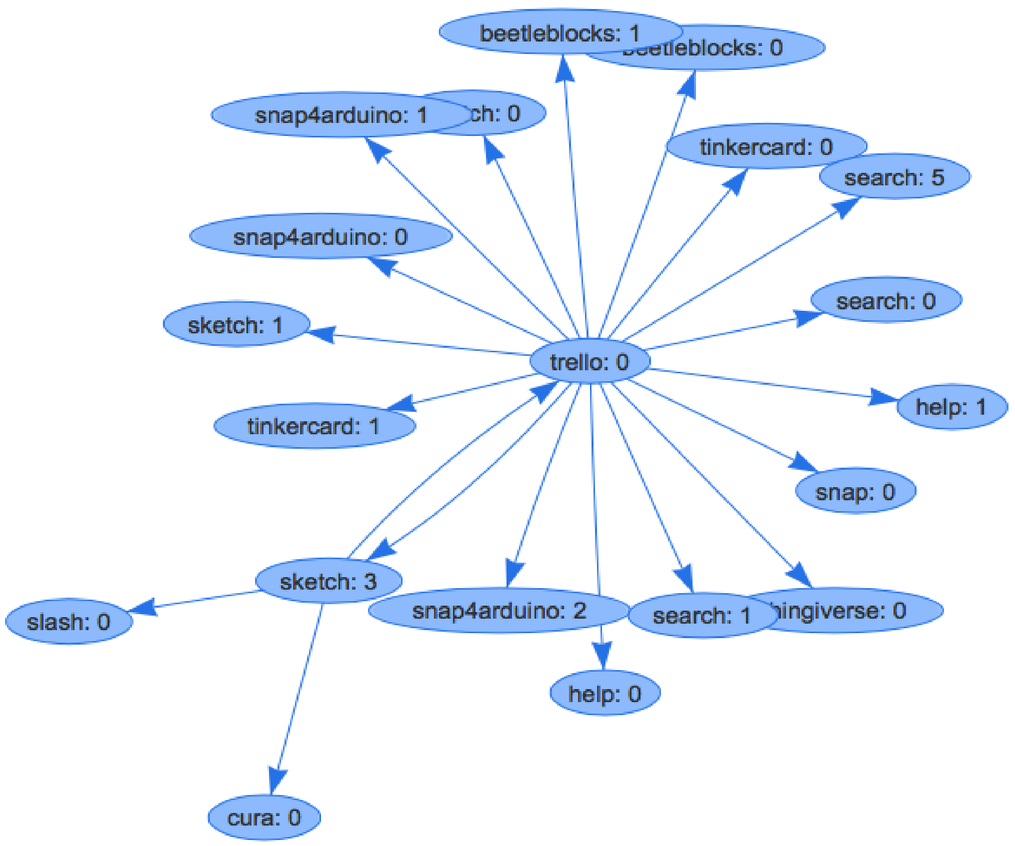


Figure 27. Graph of association rule mining algorithm

Hands-on exercises

Log in to "Pataluoto" session and group the dataset by "users". Then select which of the students you think are performing well. Remember also select the labels for the students who in your opinion are not performing well or the performance is neutral. Afterwards, launch the predict student performance tool and view the rendered decision tree. Do you agree with it?

Then, go to the main view and select the students you find anomalies. Afterwards, launch the anomaly detection tool and investigate the table. Do you think that the rows in red are really anomalies?

<u>Points of Reflections</u>

How do you see learning analytics supporting your role as a coach? What benefits are there for using a learning analytics tool? Discuss your views with your peers.

4 Transforming a Curricular Activity into an eCraft2Learn Task

In order to assist the teachers' role as coaches, a How to run an eCraft2Learn Activity Task quick teachers guide has been developed (See Annex II). This 3-step guide is expended here as follows (see Figure 28).

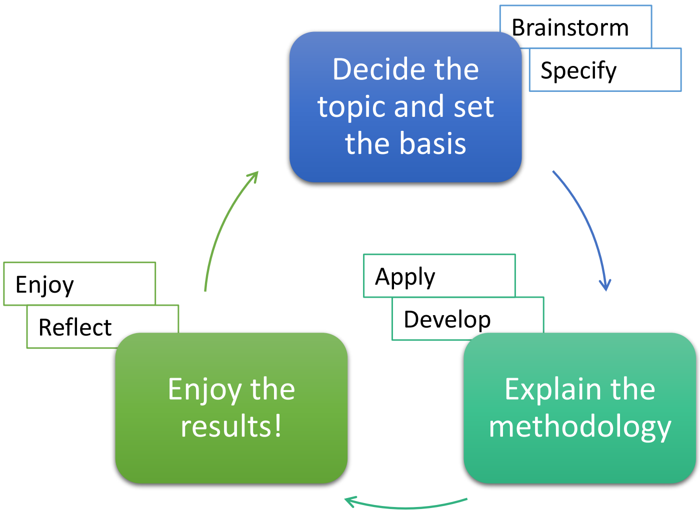


Figure 28. Quick guide to develop an eCraft2Learn task

4.1. Decide the Topic and Set the Basis

- **Brainstorm and Imagine**

  Brainstorm possible topics, areas and ideas either alone as the teacher or as a group with your students. The topic can be taken from your subject curriculum or it can be an integration of several subject areas. Make as big list as possible, no need to restrict your imagination!

- **Specify**

  Scan through the individual ideas and see if you can bring some ideas together. What could be the topic, concept or issue students are addressing? What is meaningful for them? What do they need to learn based on the curriculum? Remember to keep the topic broad enough without narrowing it down too much. You can pose an inquiry-based question to students that requires students to ponder and answer with more than one word or a sentence. The question can have multiple solutions and it inspires students.

4.2. Explain/Apply the Methodology

- **Apply**

  Once the topic is selected, explain the pedagogical methodology to your students and apply it through the eCraft2Learn learning ecosystem with the interdisciplinary topic from the five subject areas of STEAM – Science, Technology, Engineering, Arts and Mathematics

*** In science**, the aim is to explain the physical and natural world and its phenomena through observing, exploring and hypothesizing. How can the topic relate to the world around students?

* With the help of **technology**, we enhance the product or our life in general. For this, the eCraft2Learn ecosystem offers many tools. You can think how the topic could come into life with electronics (such as Arduino and different sensors) and programming tools (like Snap4Arduino). We want students to gain technological understanding, not just use it.

* **Engineering** is an application of different knowledge areas that strives to invent, design, build, create and test different structures, systems, models or materials. Briefly, engineers define the problem, then try and test until they find solutions.

* **Arts** brings the aesthetic perspective to the design process. Drawing, painting, photography, sculpting, architecture, performing arts or literature – all elements of arts. In the eCraft2Learn project, students can for example implement a theatre play with robots, use recycled materials or turn drawings into 3D models.

* **Mathematics** studies patterns, quantities and structures and fosters problem-solving skills. Students can for example discover patterns and calculate areas, volumes or dimensions. Can you guide students to apply that information to other cases or to find general mathematical rules?

Now you have all STEAM pieces ready. Let's put them together in one or two sentences to define the challenge!

It is time to create your lesson plan but remember not to make it too detailed. Students will get creative and come up with possible ways to incorporate the tools and materials when you pose the challenge or problem but make sure you have the basic idea what could be used and how. Also in order to help the time management of your project, make some preliminary schedule for how long the project can take.

- **Develop**

  It is now work time! Conduct your lesson and enjoy the process. Along the journey, be prepared for mistakes, changing plans, challenges and most of all the joy of discovering and learning.

4.3. Enjoy the Results and Reflect

- **Enjoy**

  You and your students have done well! You went through the entire process and now you can enjoy arriving at the end of the journey. Every challenge has been a learning opportunity.

- **Reflect**

  After the lesson, it is time to reflect on what happened during the class and make every challenge or fail attempt an opportunity to learn and improve. What worked and what did not? What kind of support did your students need? When were your students engaged and motivated? What did your students accomplish and learn?

5 Conclusions

This document presented a comprehensive manual for teachers' training in STEAM learning through the eCraft2Learn learning ecosystem. The document aimed at providing craft- and project-based learning STEAM training for teachers to assist in preparing to their role as coaches, facilitators and enablers of the learning experience of their students.

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ANNEX I – TEACHERS TRAINING SCHEDULE

eCraft2Learn Teacher Training Schedule Joensuu

The teachers and instructors training in Joensuu will take place 3 times a week during a two weeks period (2nd round of training, after the 1st round of small-scale pilots). Each training session will last 3 hours, for a total of 18 hours of intensive training. The teachers will also have opportunity to 'take home' assignments for them to work on (e.g., the digital environment of eCraft2Learn) in order to maximise the outcomes of the training. The flipped classroom technique will also be used throughout the work.

Day	Pedagogical outcome	Software & Hardware	Activity Description
1	- Familiarisation with the eCraft2Learn pedagogical considerations - *the role of the teacher as a coach and how to achieve it* (discussing the concepts of agile management of the eCraft2Learn activities/tasks, scaffolding the learning experience, students' self-regulation/self-awareness/self-reflection, motivation) - Familiarization with the produced open educational resources (OERs)	- eCraft2Learn UUI – how it supports the role of the coach - eCraft2Learn UUI - practical work with the OERs, feedback and improvements	- Teachers and trainers workshop on understanding the role of the 'teachers as coaches' in the classroom and how to achieve that role (50 mins) - Presentation and discussion about the OERs accessible through the UUI – guided practice (50 mins) - Do it yourself - free familiarization with the tools, exploring the communities of practices portals through the UUI and Q&A (50 mins)
2	- Familiarisation with the UUI tools and their importance in each stage to support pedagogical processes (why are these tools needed? Why have them been chosen?) - Building a project – practical experience with the AI blocks through the UUI	- eCraft2Learn UUI and technical core/laptop computers – activities highlighting the use of each tool in the UUI	- Workshop on the use of each tool in the UUI ad what pedagogical processes are supported through them (50 min) - Guided practice to develop a simple project – using the AI blocs (50 mins) - Do it yourself - free familiarization with the tools, Q&A (50 mins)
3	Familiarizing with the Snap! (and Snap4Arduino) programming environment and the AI block – how to apply them in to your own projects?	- eCraft2Learn UUI and technical core/laptop computers/tablets - programming environments and AI blocks	- Exploring the programming environments through hands on practices - guided experience (100 mins) - Do it yourself - free familiarization with the tools, Q&A (50 mins)

Day	Pedagogical outcome	Software & Hardware	Activity Description
4	Free (but plausible) project implementation - Steps to carry out an eCraft2Learn activity - Role of the teacher as a coach – scaffolding learning - AI blocks programming and applications	- eCraft2Learn ecosystem – UUI, technical core/laptops/tablets - Educational extension (AI blocks)	- Brainstorm the next lesson implementation - guided experience (50 mins) - Developing a test project – part I (curricular dependencies) – using the UUI to work through the 5 stages pedagogical approach (50 mins) – AI blocks programming and applications (issues resolution) - Q & A and free familiarization with the tools (50 mins) *Note: a specific scenario is not given here. Teachers make their own (plausible) scenario from their curricular subject matters*
5	Free (but plausible) project implementation - 3D printing project	- eCraft2Learn ecosystem – UUI and technical core/laptop/tablets - 3D printer	- Developing a test project – part II (implementation strategy, how to start the project and manage it) (50 mins) - 3D printing project - TinkerCAD for 3D design and printing (50 mins) - Q&A to find solutions to issues left incomplete during the previous sessions (50 mins)
6	-Familiarization with the concept of learning analytics in education -Familiarization with the learning analytics interface for teachers on the eCraft2Learn digital platform	eCraft2Learn learning analytics engine	- Teachers get familiar with the importance and use of the learning analytics and their integration into the UUI activities of the students (50 mins) - Guided practice with the learning analytics engine and teacher's interface (50 mins) - Do it yourself - free familiarization with the tools, Q&A (50 mins)

eCraft2Learn Teacher Training Indicative Schedule Athens

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

Week #	Scenario #	Software & Hardware	Description
4 [4 hours]	3D modeling and 3D printing skills – print simple objects	3D printer	The teachers investigate how to design and print simple objects using the 3D printer through the raspberry pi unit.
5 [4 hours]	Free (but plausible) project implementation Collection of feedback	All	No specific scenario is given here. Teachers make their own (plausible) scenario or try to find solutions to issues left incomplete during the previous sessions. At the end of this session the teachers will provide us with their feedback; they will be encouraged to comment upon the use cases developed in D2.1 as well as to speak about their experience and the extent to which the knowledge gained can improve their teaching practices.

Annex II – Quick Teachers' Guide

HOW TO RUN AN ECRAFT2LEARN ACTIVITY TASK

This guide will provide you with quick steps to start running a craft- and project-based task with your group. Description that is more detailed is given in the public deliverable document D3.4 [6]

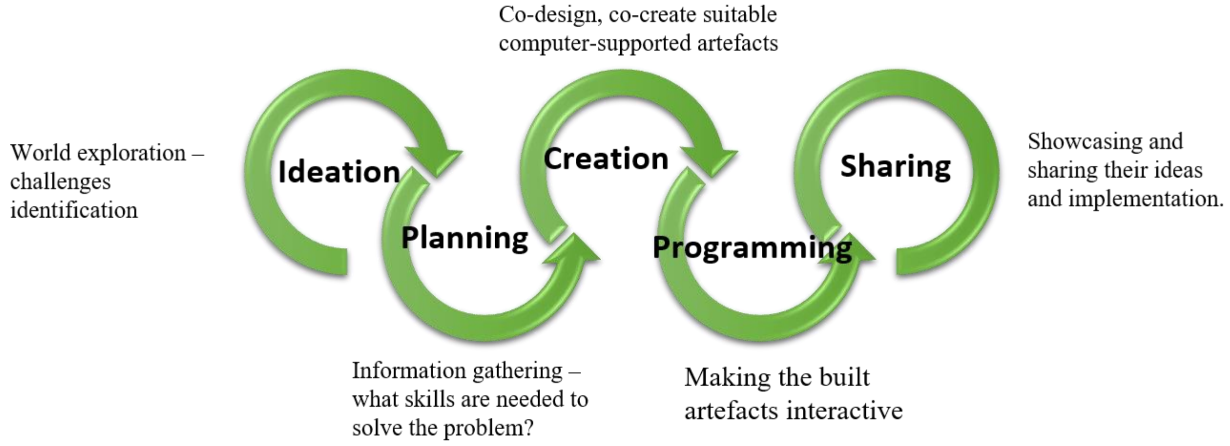
FIRST – DECIDE THE TOPIC OF YOUR TASK & SET THE BASIS

Any topic could become an eCraft2Learn topic! This means that you could for example pose a question or a challenge for students to solve. In *formal context* the topic of your task could be taken from your subject curriculum (e.g. photosynthesis, security, the new world discovery, etc.) or be an integration of several subject areas. In *informal context* you can provide more freedom for students and let their imagination fly in any topic or theme they feel curious about. Once the topic is selected, divide the students into working groups. This could be done by the teacher or by the students' self-organization.

If students need background knowledge of the task, then now is the time to provide information to them (e.g. what is photosynthesis and when it occurs?). There might also be a need to explain the basics of programming or electronics and this could be done during this first phase. Notice that the eCraft2Learn pedagogical approach is not only relying on programming or coding and so this is not a pre-requisite for the students. They will learn the skills they need during the process of *making*. Once the students have fundamental knowledge of the tools available to them, we trust that they will be confident and creative during the project.

SECOND – EXPLAIN THE METHODOLOGY TO YOUR STUDENTS

The eCraft2Learn craft- and project-based pedagogical methodology in based on five stages:



[6] Manual of craft- and project-based learning STEAM training for teachers

The students can work systematically through these stages although the work does not have to be linear. The eCraft2Learn user interface aims at assisting each pedagogical stage by providing digital tools for documenting what has happened during that stage. A simple how-to through the stages is given below:

AIM/GOAL	CONTENTS	TECHNOLOGY/MATERIALS	WAY OF WORKING
To start working with the five stages pedagogical model (see Figure above)	**Ideation/Imagine** To ideate/imagine how to create an artefact that solves or represents a solution to the given (or selected) task/problem	Laptops, smartphones, web browser, Google drive, eCraft2Learn user interface, Pinterest Peer teaching can be used during the exploring a new working plate (crossing the group boarders)	Notetaking, conversation in groups, together, mind mapping, making collage or with other technique. eCraft2Learn-platform is supporting the ideation as well as YouTube-videos (of DIY, robotics)
To plan the artefact	**Planning** To assign roles within the group – who will do what in order to arrive at a suitable solution to the given (or selected) task/problem. To understand what strategies are needed to carry out the task	eCraft2Learn platform. During the planning students, make list of the material they will need for their artefact and activities they need to perform.	Students set a target for their working and organise the division of labour Making a collage
To start to create the artefact	**Creating** To physically make the artefact or solution that the students had imagined and planned	eCraft2Learn platform Recycled material 3D-printers Electronic components (e.g. LEDs, sensors, etc.)	Organised in the division of labour
To make the programming for the artefact	**Programming** To bring the created artefact to life!	Possibility to use Snap, Scratch, some already-known app The eCraft2Learn platform/ instructional videos	Creating, programming proceed hand in hand
Sharing the result of the process (artefact)	**Sharing**	eCraft2Learn –platform	Presenting the artefacts to each other and through the platform/social media

THIRD – ENJOY THE RESULTS!

Notice that your role in this process will be more of a coach or facilitator to the learning experience. It is important to let the students explore the topic given and foster their imagination to bring about solutions to the tasks. The eCraft2Learn user interface offers assistance understanding the basic principles of the technology to be used during creation and programming, for instance. However, the students should be encouraged to delve deeper into obtaining the needed knowledge to succeed in the task. The source of knowledge could be internet search as well as traditional books and peer-learning.

ANNEX III – D3.4 M8

eCraft2Learn

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

Deliverable D3.4

Manual of project- and craft-based learning STEAM training for teachers

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 731345.

PROJECT DESCRIPTION

Acronym:	**eCraft2Learn**
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Coordinator:	University of Eastern Finland
Reference:	731345
Type:	RIA
Program:	HORIZON 2020
Theme:	Technologies for Learning and Skills
Start:	01. January, 2017
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Website:	http://www.project.ecraft2learn.eu/
E-Mail:	office@ecraft2learn.eu

Consortium: **University of Eastern Finland**, Finland, (UEF), Coordinator
Edumotiva, Greece (EDUMOTIVA)
Mälardalen University of Sweden, Sweden (MDH)
Zentrum für Soziale Innovation, Austria, (ZSI)
The University of Oxford, United Kingdom, (UOXF)
Synyo GmbH, Austria, (SYNYO)
University of Dundee, Scotland, (UNIVDUN)
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DELIVERABLE DESCRIPTION

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Authors:	**Hanna Nygren, Kati Mäkitalo-Siegl** (UEF)
Contributors:	**Margit Hofer,** ZSI
	Marie Ehrndal, ARD
	Sophia Manika, TECHNOPOLIS
	Calkin Suero Montero, UEF
	Christian Voigt, ZSI
	Andrea Alessandrini, LNU
	Dimitris Loukatos, EDUMOTIVA
Reviewers:	**Alex Jonsson**, EVOTHINGS

Version Control

Version	Date	Person in charge (Organization)	Changes	Quality Assurance
1	15.8.2017	Hanna Nygren (UEF)	Draft version	Kati Mäkitalo-Siegl (UEF)
2	30.8.2017	Hanna Nygren (UEF)	- Updates based on partner comment	Alex Jonsson (EVOTHINGS)
3	31.8.2017	Hanna Nygren (UEF)	- theory for personalised learning supplemented - minor changes made considering the section of the technology	Kati Mäkitalo-Siegl (UEF)

Acknowledgement: This project has received funding from the European Union's Horizon 2020 Research and Innovation Action under Grant Agreement No 731345.

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EXECUTIVE SUMMARY

This deliverable will design and develop teacher education and training courses material taking into account the following features: personalised and adaptive learning context including the concepts and the elements of craft- and project-based learning pedagogical approach; offering positive experience through hands-on activities; and support for orchestrating the whole process including the management of the technological resources. This deliverable consists of the basics of the project- and craft-based pedagogy, STEAM education and opens the basic concepts of the technology that is being used during the training – including the plan for the training.

1 INTRODUCTION

This deliverable will design and develop teacher education and training courses material taking into account the following features: personalised and adaptive learning context including the concepts and the elements of project- and craft-based learning pedagogical approach; offering positive experience through hands-on activities; and support for orchestrating the whole process including the management of the resources (3D printers, DIY electronics, etc.). This deliverable can serve as pre- and in-service teacher education in order to prepare teachers to implement eCraft2Learn in schools. In the workshops, teachers are prepared to their new roles as coach, facilitators, and enablers. Given the teachers hand-on experiences on how to work with the eCraft2Learn ecosystem (Figure 2) in the same ways that they are expected to work on and act in it with their students.

2 FOUNDATIONAL KNOWLEDGE OF PROJECT- AND CRAFT- BASED LEARNING - STEAM TEACHER TRAINING

"Imagination is more important than knowledge" - Albert Einstein

STEAM is used here as an educational approach to learning. In this approach, **science**, **technology**, **engineering**, **arts** and **mathematics** are seen as access points for guiding student activities, such as inquiry, dialogue and critical thinking, which enhance learning. This approach is assumed to produce students who take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration and work through the creative process. With regarding the arts and the skills students are expected to possess can be developed through product design, where introducing new digital technologies can encourage the incorporation of new materials and disciplines.

The eCraft2Learn framework is built on the ideas of inquiry- and design thinking-based approaches. We shall utilise an inquiry-based approach, more specifically called project-based learning (PjBL), which is based on the idea of inquiry and problem-solving processes. In PjBL, the learning process is constructed around projects in which the students are working (see Blumenfield et al., 1991). Students have the freedom to choose the subject matter and to define the central content of the project they want to work with. Products like computer animations and websites can trigger communication and collaboration (see Blumenfield et al., 1991; David, 2008; Helle, Tynjälä, & Olkinuora, 2006; Tal, Krajcik, & Blumenfeld, 2006). Students develop their own questions, which are open-ended and which may lead to diverse solutions (Savery, 2006).

The cross-cutting idea of the eCraft2Learn pedagogical design is personalised learning, which is a progressively student-driven model. Zmuda, Curtis and Ullman (2015, p. 7) note that in "personalised learning, a student is deeply engaged in meaningful, authentic, and rigorous challenges to demonstrate desired outcomes". Personalised learning also serves as a base for a project-based approach because of meaningful and authentic challenges. Moreover, the project-based approach includes different stages whereby the student is proceeding progressively. It is a student-driven model with more or less degrees of freedom, depending on the student's prior knowledge and experience and the task and goals of the curriculum.

21st-century skills include i.a. of skills of collaboration - negotiation and communication - and creativity, critical thinking, problem-solving and learning to learn skills as well as ability to use technology and engage in real-world tasks (see Bell, 2010; Binkley et al., 2012; OECD, 2010). These skills are reported to be the core skills in the knowledge society as well as in the work life. Students should embed these skills when finishing their basic education for being ready for further continuing their studies and taking steps to the work life. The nature of working life is changing rapidly, just like the society as a whole, therefore we cannot prepare our children for something that is not yet known, but equipping them with the skills that they manage is the best thing to do. Because the information and technology are available, but the skills on how to get the information what is needed, how to utilise it and how to make the best out of technology, we create the ecosystem around this project where we can practice these skills in the safe environment.

We do know that inquiry-based learning processes and working in teams can be challenging for students (Kollar, Fischer, & Slotta, 2007; Linn, 2006). In particular, when students are mostly working in teams, they face several challenges, which might occur due to lack of engagement on knowledge-construction processes regarding formulating questions, challenges, collecting evidence, interpreting results, explaining and evaluating these explanations and the process or different processes of project work (Mäkitalo-Siegl, Kohnle, & Fischer, 2011). Therefore, support should be offered in order to help students with the inquiry-based and design-thinking processes as well as with working in teams. This kind of support might require expert guidance or scaffolding as well as small group scripting. However, an open question is whether those students who are facing challenges are using the help that is available from multiple sources (e.g. teachers, peer learners, experts, the online environment; see Mäkitalo-Siegl & Fischer, 2011; Huet et al., 2013).

We endeavour to connect the project to a realistic context – students' everyday life – so that they can see the relevance of this project and the connection between school (school subjects) and the world outside of school (see also digital fabrication and making in education; Blikstein, 2013; Gershenfeld, 2007). Students explore the world in order to identify questions or puzzling situations, which might then turn out to be a problem for which they have to find a solution. The student is active, taking responsibility for his or her own learning. It gives him/her an opportunity to engage in an in-depth investigation of worthy topics. This approach gives the learner greater autonomy when constructing personally-meaningful artefacts, which are seen as the representations of their learning (Grant, 2002, p. 1).

STEAM provides a way to engage boys and girls of all ages to explore the idea of electronics and technology (Magloire & Aly, 2013). The inclusion of arts and craft in science projects enable a space for creativity and innovation during the process. Electronics and technology as learning subjects usually attract more boys than girls, and girls have traditionally been more attached to artefacts when the product was meaningful to them (Magloire & Aly, 2013). According to Fristoe, Denner, MacLaurin, Mateas and Wardrip-Fruin (2011), girls' interest in creating games is mainly in the context of *relationships, social interactions and storytelling*. Therefore, working in teams could fascinate girls because of the social interaction aspect (Mäkitalo-Siegl & Fischer, 2013) as well as arts and craft (Magloire & Aly, 2013) to work with projects involving electronics and technology. Weber and Guster (2005) have studied gender-based preferences towards technology. The population of their study consisted of middle school students and high school technology education classes. They found no differences in activity between genders; however, significant differences were found in relation to design and use. "Females found design activities more interesting whereas males preferred utilising types of activities" (Weber & Guster, 2005, p. 59). "Since making is based on what is personally relevant to an individual, it allows people of all backgrounds to pursue their interests and to use technological tools to develop their own projects. It can create more channels for girls to positively identify with computer science and engineering fields" (Intel Report, 2014 p. 7).

3 PERSONALISED LEARNING AND ADAPTIVE SYSTEM

Every student has an individual background of knowledge, experience and skills. Personalised learning aims to tailor teaching to individual needs, interests, and aptitude to ensure that every learner achieves and reaches the highest standards possible (Heller, Steiner, Hockemeyer & Albert 2006, 75). Therefore, we need a system that can adapt the personal needs and interest of learners in order to provide both learning content and pedagogic environment/methods for the student (Nguyen & Do 2008, 395). The eCraft2Learn-ecosystem will adapt to the need of the students and teacher.

The cross-cutting idea of the eCraft2Learn pedagogical design is personalised learning, which is a progressively student-driven model. Zmuda, Curtis and Ullman (2015, p. 7) note that in "personalised learning, a student is deeply engaged in meaningful, authentic, and rigorous challenges to demonstrate desired outcomes. Personalised learning also serves as a base for a project-based approach because of meaningful and authentic challenges."

Miliband (2006) defines the personalised learning through five components. 1) It emphasizes knowing the strengths and weaknesses of each student and the assessment of learning. 2) Developing the competence and confidence of each learner through teaching and learning strategies that build on individual needs. 3) Every student has the possibility to enjoy the curriculum choice – they are engaged and excited by the curricula. 4) The starting point for the class organisation is always student progress. 5) The community, local institutions and social services support schools to drive forward the progress (Miliband 2006, 25-26).

By using the project-based method, where different stages are included the student proceeding progressively and by their own pace as well as selecting the theme based on their interest. Therefore, we could state that project-based method used is supporting personalised learning. Moreover, it is a student-driven model with more or less degrees of freedom, depending on the student's prior knowledge and experience and the task and goals of the curriculum.

The assumption is that the students don´t have much previous experience of making robots - they choose the path for their learning approach which can be more advanced or for beginners. Students are able to choose their learning/working path through the platform which includes short videoclips that instruct students to plug the wires, to programme and execute the 3D printing. These videoclips are also presenting innovative artefacts and what previously has been done.

4 THE ECRAFT2LEARN PEDAGOGICAL FRAMEWORK

The eCraft2Learn pedagogical framework is developed within five stages and is based on the idea of the project- and craft-based learning within open learning scenarios. The five pedagogical stages are as shown in Figure 2. The students´ learning process is supported in every stage with proper technologies which are a part of the eCraft2Learn ecosystem as well as teachers and experts are.

The eCratf2Learn project- and craft-based learning methodology consist of five stages; ideation, planning, creation, programming and sharing (Figure 2), that aim at learning through projects and producing a computer-supported artefact. Usually, inquiry-based learning is initiated when students pose questions, problems or scenarios and the process is supervised by a "coach" (teacher acting as a coach). Students identify study issues and formulate questions in order to develop their knowledge or solutions. The process is intrinsically argumentative, where the students create questions, obtain supporting evidence to answer the questions, explain the evidence collected, connect the explanation to knowledge obtained from the investigative process and finally create an argument and justification for the explanation. Inquiry-based methods are usually related to scientific activities and scientific thinking in STEM. However, we refer to STEAM when there is need to take into account arts and craft and therefore, we integrate inquiry-based method with Design Thinking method where hands-on activities are highlighted.

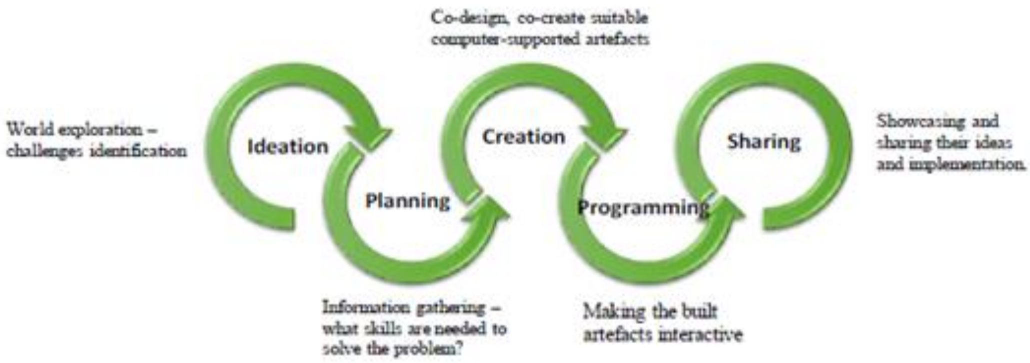

Figure 1: Five stages of craft- and project-based learning methodology

5 ECRAFT2LEARN-ECOSYSTEM

Elements of educational ecosystems include e.g. redesigning (physical) learning spaces, Integrating physical learning materials (e.g. electronics or 3D-printed ones) with their software counterparts (e.g. simulations) and remodelling and training for teachers (see Dillenbourg, 2008). The eCraft2Learn ecosystem is designed and developed to work as the pedagogical framework which is based on open education resources. The learner plays an active role in the practical making of connected artefacts. The eCraft2Learn pedagogical model enhances learner's awareness of learning process and self-regulation (which includes self evaluation). It promotes the learner's pathway by enhancing the design of technology implementation and designing the necessary support available (WP4). Pedagogical model also meets users' needs and increase users' engagement through a participatory design approach. Model supports teacher's role as a coach. The eCraft2Learn framework is designed to support learners, teachers, peers and sometimes facility managers in making the crafts-based learning ecosystem happening. (see Technical annex, eC2L)

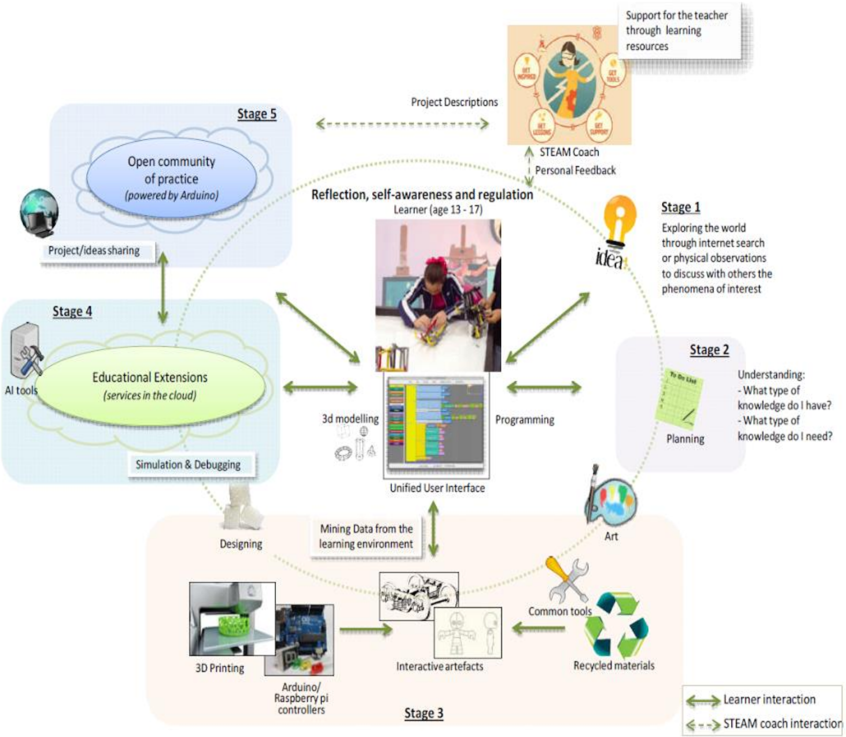

Figure 2: eCraft2Learn ecosystem indicative scenario

5.1. ROLES IN ECRAFT2LEARN ECOSYSTEM

The eCraft2Learn ecosystem deploys a craft- and project-based methodology. The ecosystem consists of a web-based eCraft2Learn working platform, aimed to cater for all relevant stakeholders; learners, teachers (coach, facilitator) and experts. The eCraft2Learn learning ecosystem creates a collaborative, open, playful and non-judgmental environment that supports learners' creativity. Learners are encouraged to walk around and collaborate freely with other students and to share ideas and solutions with peers and teachers.

Students are learning peers, each with their own set of strengths and weaknesses. They all are somewhere on the learning curve, and by helping each other and working together they progress together, often faster than when working alone. As the project advances, they learn with and from each other. Students can take on roles during the process of building their personal skills. Everyone has a chance to participate with his/her own know-how. According to Robertson et al. (2013), design team members may work in different roles during the process, e.g. project manager, technology specialist, design partner, researcher, learning scientist, collaboration facilitator, etc. In this way, students learn that more heads are better than one and that different people have different expertise, which contributes to richness. They learn how to collaborate, communicate and reason (critical thinking skills) and how to be creative in a group.

The role of the **teacher** or ‘coach’ is to facilitate and steer the learner and the project ‘back on track’ when needed. The teacher, who most likely already knows his/her students, encourages them to explore and seek information from different sources instead of giving complete answers. The teacher also encourages peer learning, discussion and exploration. According to Boling and Smith (2014), the one who works as an instructor spends the working time discussing with students and confronting their challenges.

The eCraft2Learn working platform is designed to be easy to approach and use. The platform encourages the learner to share thoughts and ideas. It contains videos on creating DIY artefacts and references hyperlinked to reliable, original information. At the same time, the platform works as a portal where previous projects are documented. On the eCraft2Learn working platform, there is an opportunity to get online help from an expert who has the requisite knowledge. Experts encourage students to ask questions and present their ideas. Experts give concrete examples, share their own knowledge, give constructive and positive feedback. In the online platform, students can utilise carefully planned prompts in order to help them to proceed to each stage.

Experts can assume different work roles to support the learner through challenges encountered during the project in online or face-2-face situations. The expert’s role thereby varies during the five steps of eCraft2Learn’s project-based learning. The student can be seen as an active worker who works in the group, explores, finds solutions to authentic challenges, searches for information and solves problems. Experts can work with coding, robotics and design. In the following segments, there is a more detailed description of the stages of craft- and project-based learning with the role descriptions included in each stage.

5.2. DESCRIPTION OF THE WORKSHOPS IN MAY 2017

In order to preliminary test the suitable integration of the 5 stage pedagogy with the core technology hardware and software tools we selected for the eCraft2Learn ecosystem, a preliminary eCraft2Learn Workshop was organized in May 2017 in Joensuu SciFest 2017 international event. Five groups of around ten participants (aged 10 to 16) from five different schools were divided into smaller groups to create ‘robot heads’. Creating the robot heads proceeded based on the idea of five stages of craft- and project-based learning methodology; (1) Ideation, (2) Planning, (3) Creation, (4) Programming, and (5) Sharing. Notably, the first three stages seemed to mix during the development of the tasks, and *during this trial, these stages were not supported by all the technologies described here (3D printer was not available)*. Students had all the crafting material on their tables (e.g. paper, carton boxes, toilet paper rolls, scissors, pencils, tape, glue, LEDs, wires, sensors, etc.), as well as a Raspberry Pi computer running Scratch4Arduino (S4A) connected to an Arduino Uno running the S4A firmware, for programming. Students had a chance to explore programming first before starting to define their challenge. Pedagogically, creating and programming were integrated but only one group started with programming. The goal of programming was to make the eyes of the robot blink. After the eagerness of creating the robot head using all the material on the table, the enthusiasm diminished, as there was a time gap between the creation of the actual head and the programming session.

The technologies used in the workshops (RPis, Arduino boards, S4A software, and other electronic components) were suitable considering the development and the previous experience of the students. Still, clear and short instructional videos may be needed to help students to perceive what measures have to be done and in which order. This could ease to use the technologies and make it more approachable.

5 MATERIAL KIT

This section includes the basic information for the teachers about the technology which is used during the eCraft2Learn -teacher training. The material kit includes tools and materials for working. Creating an artefact in this context boils down to making something that makes daily life better, easier or more fun. The artefact is planned and prepared by using recycled materials combining them to new materials (3D-printing, led-lights, programming).

The level of complexity can be changed depending on what electronic components are included. This also supports the idea of personalized learning where the student can pick an appropriate and purposeful learning path. Drawing circuits with conductive ink or shaping conductive clay creates the same end result as soldering wires onto a PCB. And while visual and textual coding can produce the same result, the level of complexity is very different, as is the learning outcome.

In order to practice innovation, it is important that learners feel comfortable to go beyond the intended use of electronics and feel encouraged to explore alternative methods and uses for the tools at hand.

5.1 DIY ELECTRONICS

The maker culture is a hacker-related, technology-oriented culture deriving from Do It Yourself (DIY) culture. While DIY methods include building, modifying, and repairing objects without the direct involvement of experts or professionals, maker culture is similar; focused on the creation of new technological objects, or tinkering with existing ones. The interest of maker and DIY electronics have been growing ever since these tools and technologies became available outside the industry. Today, they are more affordable, accessible, easy to use, and in a democratising context based on information sharing philosophies derived from the open source movement. Programmable microcontrollers and computers such as the Arduino and Raspberry Pi, are often user-friendly and widely used by 'DIYers' and makers around the world. Contemporary, commercially available DIY electronics can be said to have a varying degree of difficulty of use. With everything from the plug and play magnetic components like Little Bits, to Arduino board kits with regular electronic components and documented experiments, and Raspberry Pi microcomputers - all with a wide range of learning materials accessible online. The choice of platform and electronics largely depends on target group and goal of use.

The availability of easy to use and cheap electronics, coupled with rich documentation and information sharing culture, has inspired pedagogues to integrate elements of maker culture into their classrooms. This kinesthetic hands-on learning approach has been seen as a complement existing pedagogical methods and materials.

We are referring to simple components, like connector cables, breadboards, photo resistors, potentiometers, servo motors and LEDs, which all can be used in conjunction with the RPI and the Arduino units, to implement the designed artefacts. These DIY electronics components, in conjunction with the RPI and the Arduino units and 3D printed parts, can cause a significant change for the better in how we learn.

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

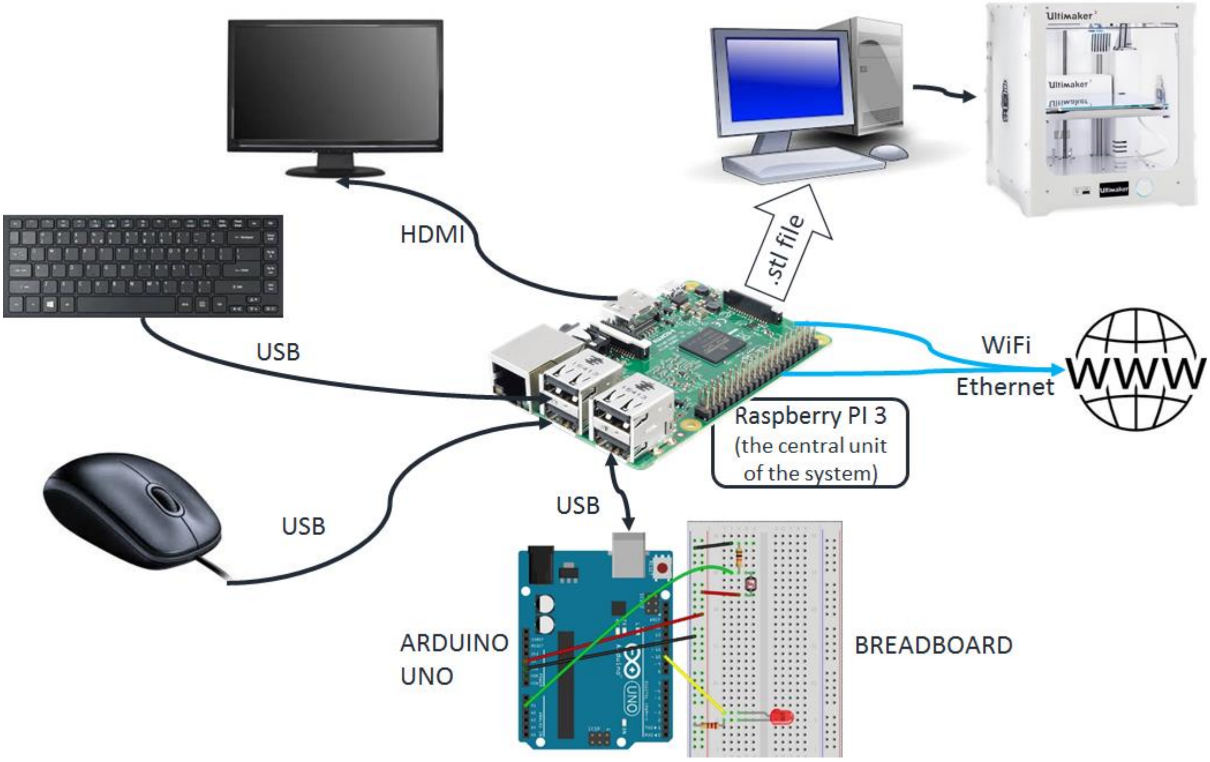

Figure 3: Representative hardware architecture of the technical platform in the eCraft2Learn ecosystem with a PC controlling the 3D Printer for generality. In the next months an implementation with a RPI3 controlling the 3D Printer will be investigated.

5.2 Wiring the various components

Two kinds of wired connection actions are necessary in order for the laboratory to operate and the artefacts to work. The first tackles with power supply and interconnection issues of the fundamental components of the lab, like the 3D printer, the Raspberry Pi based workstations or their screens. The second tackles with powering up and interconnecting the artefact themselves.

5.3 Arduino

Arduino boards are made to enable non-engineers to create interactive objects using electronics and programming. The board design, its extensive online documentation and online community makes

Arduino an ideal platform for learners. As Arduino was born out of the need to teach through hands-on prototyping, a beginner can easily make interesting things happen with little previous knowledge of electronics and coding. This enables learners to understand the general concepts early. The eCraft2Learn Raspberry Pi device, that as opposed to the Arduino is used as a desktop computer, will be used to communicate with external devices. In most cases, these external devices will be Arduino UNO boards, which in turn are exploited to implement computer supported artefacts. The user can the program, monitor and communicate with these artefacts - via the Arduino UNO boards - from the RP3 device interfaces.

5.4 RASPBERRY PI

Raspberry Pi [https://www.raspberrypi.org/] is a credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games. Furthermore, the Raspberry Pi has the ability to interact with the outside world, and has been used in a wide array of digital maker projects, from music machines and parent detectors to weather stations and tweeting birdhouses with infra-red cameras. (Deliverable 4.2)

Figure 4: Raspberry PI 3

5.5 PRINTING

3D printing is widely used in different fields like in the medical field, healthcare and in surgery as well as in architecture and industry. The inclusion of 3D printing technology into the eCraft2Learn ecosystem, provides students with a means to design and manufacture physical components and/or parts that will integrate with the DIY electronics eg Arduino, in order to make their artifacts. This provides a real link between craft based activities in school with actual product development practices in industry. The eC2L-working platform includes examples of 3D printed artifacts/project integrated with DIY electronics.

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

A NIOSH Research Rounds publication recently published a study that discusses health and safety considerations when working around 3D printers. Particle emissions are the focus, especially when multiple printers are running simultaneously. Another consideration is toxic vapors that can be generated by heating plastics. Safety recommendations include the following:

Use 3D printers ONLY in properly ventilated areas.

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

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

- Building/Room where 3D printer will be located
- Placement of the 3D printer in the space itself
- Selection of printing feedstock

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

Hazards

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

Dos

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

Don'ts

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

Ultimaker 2+

This is the most common choice of Ultimaker 3D printer currently for schools as it is a great value all-around professional desktop 3D printer that delivers consistent results. Engineered to perform, the Ultimaker 2+ is user-friendly. With a simple display and control dial, even young students can operate this printer independently with a little prior instruction. The Ultimaker 2 Extended+ offers the additional benefit of an additional 10 cm of build height, perfect for larger prints that students may require.

Ultimaker 3

The Ultimaker 3 (fig. 4) is the most reliable dual extrusion 3D printer available, allowing students to print models in 2 colours or materials without pausing the print. This professional desktop printer allows for prints with more complex geometries to be created by using dissolvable PVA for printing the support structures. This provides greater opportunities for the student to realise more complex designs.

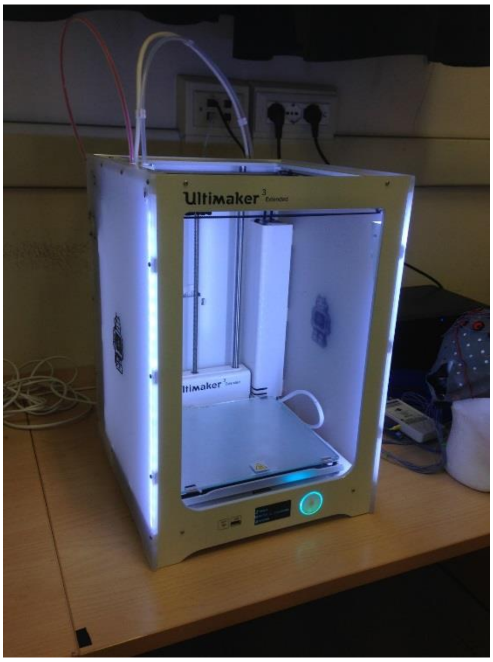

Figure 5: Ultimaker 3 printer

5.6 ECRAFT2LEARN-PLATFORM

The eC2L-platform is built to support the Five stages of craft- and project-based learning methodology (Figure 2). The platform provides support for ideation, planning, creation, programming and sharing. The platform includes relevant information produced and collected by professionals of technology and education. The idea is that the platform itself promotes the process of creating an artefact but also sharing ideas.

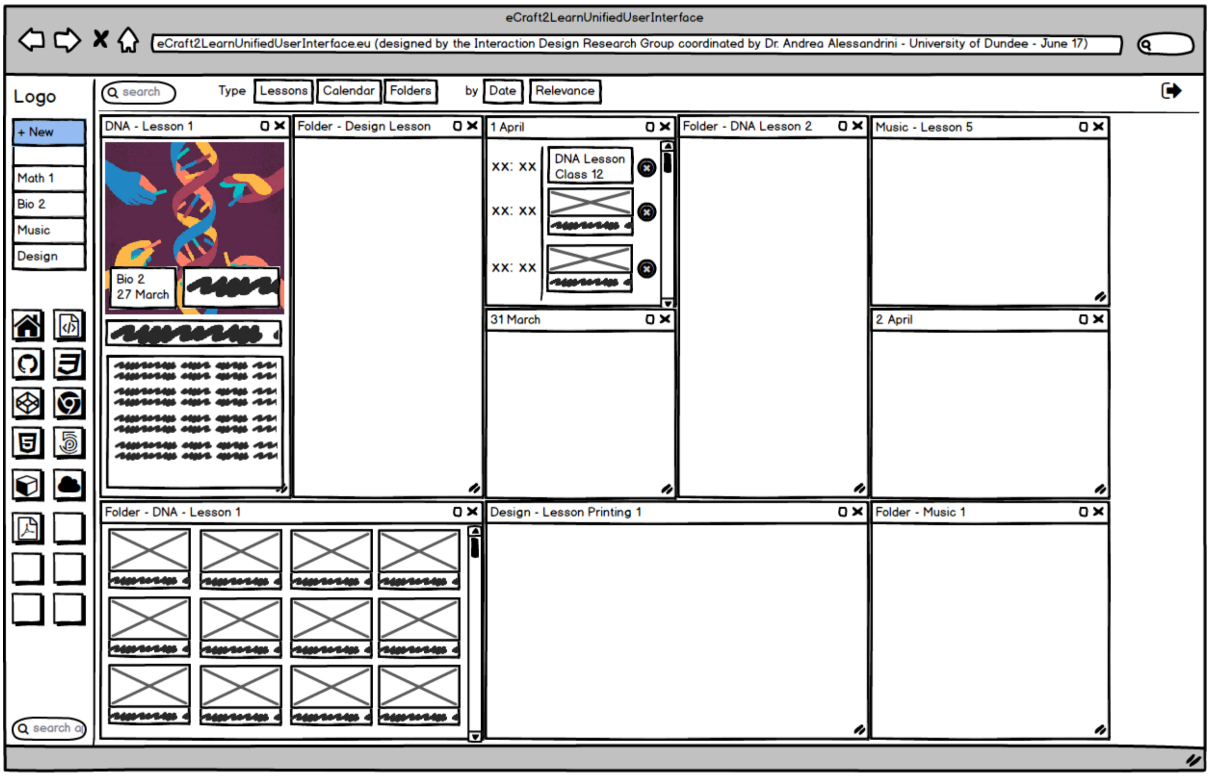

Figure 6: Sketch of the eCraft2Learn User Interface (UI)

5.7 AT THE END OF EACH LESSON

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

6 TRAINING PLAN FOR TEACHERS (20 H)

The intention of the workshop is to provide a model of teaching robotics, make it more approachable and easy. The aim is that the teachers will go through the same operations as their students. The workshop starts with “throwing teachers into the cold water”. After giving short and simple instructions the teachers are asked to build a robot head as in the pilot workshops during the SciFest 2017. Teachers are asked to give feedback of what they found familiar and what challenges they faced. They are also asked to ponder the integration into the curriculum.

1. Training plan 4X45min. ***“Throwing to a cold water - Build a robot head”***

AIM/GOAL	CONTENTS	TECHNOLOGY/MATERIAL	WAY OF WORKING
Knowing each other and forming the teams To **build a robot head** with the given instructions	Short instructions are given to teachers (“Andrea´s concept”) following the basic pedagogical element: 1. Ideation 2. Planning 3. Creation 4. Programming 5. Sharing Teachers are shown some photos of robot heads created by children in workshops at SciFest	Recycled material (before these lessons teachers may be asked to bring some material)	Working in groups, self-guided, problem-based
Teachers get their first impression of building robotics	Teachers start creating a robot head i n groups	Material kit is provided for teachers as well as the instructions for making a robot head Arduino RasperryPi Material for wiring	
To get feedback from the teachers - teachers reflect in groups (and share it to others) *what was difficult, what went well, what was learned,* ***how the done things were connected to curricula***	Discussion in groups/ sharing the results (artefacts and thoughts)		Feedback/ shared discussion Time for questions, wondering and pondering

2. Training plan 4x45min. *"GIVING THE TOOLS TO PLAY"*

AIM/GOAL	CONTENTS	TECHNOLOGY/ MATERIAL	WAY OF WORKING
45 min. Opening the **basic concepts** (eC2L, STEAM) > finding the connections to curricula Present the idea of "Five stages of craft- and project-based learning methodology"	Brief overview of Lab's environment Teachers to become familiar with the laboratory equipment Students are divided into smaller groups *Teachers create a mind map of connections to curricula*	eC2L-platform (supporting the presentation) Arduino uno Arduino IDE Ardublock or similar Sensor and actuator components	Small groups (facilitated by the trainer, discussion, creating mind maps)
45min. **Wiring (leds)** going through the basic idea of wiring (instructed by trainer & platform) **Arduino** **RasperryPi**	Teachers are divided into groups to sort out the principles of - Arduino & wiring (leds) Activities focusing on tablet devices visual programming and interconnection with RPI3 or Arduinos.	eC2L-platform Arduino uno Arduino IDE Ardublock or similar Sensor and actuator components Raspberry Pi 3 units remotely connected Sensor and actuator components	Peer learning Small groups
45min. **Familiarizing with 3D-printing (snap, scratch)** (maker too) - "Playing with printer" - "It takes 30min. To learn the basic settings"	Teachers are instructed to print - an existing model - they are given certain forms that they have to code (Snap, Scratch) print/ create something special (playing)	Ultimaker 3D-printer Videos on platform Trainer demonstrating Giving the possibility to use Snap and Scratch (or the apps that are familiar)	Peer learning
45 min. **Feedback/presenting and discussing what has been made**	Reflecting what has been learned? What could be the pitfalls considering the students (children)?		Peer learning

3. Lesson plan 4X45min. "STARTING THE CREATION OF AN ARTEFACT"

AIM/GOAL	CONTENTS	TECHNOLOGY/ material	WAY OF WORKING
Starting to create an artefact that can ease the everyday life (Facilitator presents the challenge) **Exploring the eC2L-platform and using it for ideation and planning** To ideate and plan an artefact which can solve a real life problem	Defining the problem Opening the eC2L-plaform, exploring it with the trainer, getting inspiration	eC2L-platform Videoclips (on the platform) of innovations and artefacts, what has been done 3D-printers, RasperryPi, leds (facilitator remind that above-mentioned tool are in use) Recycled material (combined with new material)	Students define the problem through conversation, making notes, taking photos.
To start working with the five stages pedagogical model (Figure 2)	1. **Ideation**	laptops, smartphones, web browser, google drive, eC2L-platform, Pinterest Peer teaching can be used during the exploring a new working plate (crossing the group boarders)	notetaking, conversation in groups, together, mind mapping, making collage or with other technique eC2L-platform is supporting the ideation as well as YouTube-videos (of DIY, robotics)
To plan the artefact	2. **Planning**	During the planning students make list of the material they will need for their artefact and activities they need to perform.	Students set a target for their working and organise the division of labour Making a collage
To start to create the artefact	3. **Creating**	eC2L-platform Recycled material 3D-printers RasperryPi leds	Organised in the division of labour

4. Lesson plan 4X45min. “CONTINUING WITH WORKING”

AIM/GOAL	CONTENTS	TECHNOLOGY	WAY OF WORKING
To continue creating an artefact	3. **Creating**	eC2L-platform 3D-printers	Peer learning/support Lesson is used for working, creating the artefact,
To start programming the artefact	4. **Programming**	Also previous apps can be used	Peer learning/support

5. Lesson plan 4X45min. "FINISHING AND PRESENTING"

AIM/GOAL	CONTENTS	TECHNOLOGY	WAY OF WORKING
To make the programming for the artefact	4. **Programming**	Possibility to use Snap, Scratch, some already-known app The eC2L-working platform/ instructional videos	Creating, programming proceed hand in hand
Sharing the result of the process (artefact)	5. **Sharing**	eC2L-platform	Presenting the artefacts to each other and through the platform/social media
Making a lesson plan (connected to research)	Teachers are creating a short lesson plan this works as a document what has been learned	Lesson plan is being shared on platform	Individually

7 CONCLUSION

This deliverable offers the basic information about craft- and project-based learning and STEAM education for training the teachers. This deliverable consists of the basics of the project- and craft-based pedagogy, STEAM education and opens the basic concepts of the technology that is being used during the training. The deliverable also includes the procedure of training. In the heart of this deliverable are the 5-step pedagogy and the idea of giving a tool to teachers to teach robotics and ease their path into it.

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