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

Deliverable D5.3

Recommendations for Ecosystem Refinement and Improvement

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EXECUTIVE SUMMARY

This deliverable D5.3 puts forward recommendations for improvements for the eCraft2Learn learning ecosystem as obtained through the practical implementations and testing during the project 1st round of small-scale pilots. An explanation of the type of qualitative data collected is presented as alongside the mechanisms used to synchronise the work in Greece and Finland. The recommendations are given from the perspectives of usability of the developed or integrated tools in the digital platform (UUI), the physical technical core as well as the pedagogical core of the ecosystem. The deliverable informs the improvements to take into account for the further development, implementation and testing of the eCraft2Learn ecosystem.

1 INTRODUCTION

Deliverable D5.3 oversees the production of recommendations to the eCraft2Learn learning ecosystem adjustment and improvements from the perspectives of the technical core, the pedagogical core as well as the usability of the implemented digital tools. The data collection methodology and mechanisms used are explained in detail here.

This document informs the development of the eCraft2Learn ecosystem by providing recommendations based on the results of observations, interviews, learning diaries and lesson diaries obtained from teachers and students during the 1st round of small-scale pilots in Greece and Finland (activity period November 2017 - March 2018). The recommendations also include the results of discussions on technical and pedagogical aspects of the project among project researchers from the partner intuitions.

Teachers and after-school instructors were recruited through open call in Greece. In Finland, teachers from high schools were recruited through personal contact through the City of Joensuu Media Centre and after-school instructors were recruited through direct contact with local after-school tech clubs. The participation of the teachers and instructors was voluntary[1]. Table 1 shows the number of participants during the 1st round of pilots in both countries.

Table 1. Number of participants in the pilots

	Greece		Finland	
Context	**Formal**	**Informal**	**Formal**	**Informal**
Teachers/instructors	12	5	5	4
Students	24	25	58	15
Total participants	36	30	63	19

In this report, the results of the data collection (e.g., observations, interviews, focus groups, etc.) are given from the perspective of each country were the pilots are deployed (Finland and Greece). This is because, even though the data collection mechanisms used were the same in both countries, the researchers noted and observed not only the aspects that were set to commonly be observed in both countries, but also other aspects, behaviours and interactions that were related to the local context where the data were collected.

[1] In Greece, interested applicants registered their interest online using the following link: http://edumotiva.eu/limesurvey/index.php?sid=27146&lang=en
Three face-to-face meetings were held with the applicants in Greece to explain to them in detail the eCraft2Learn educational and research initiative and their responsibilities. In Finland, one meeting was held to explain the project and research initiative to the teachers and instructors that volunteered to participate.

The differences in the observed data were also influenced by the local culture, the type of topics and activities that were carried out as well as the perspectives of the observer on the actions that they considered of importance to notice. From this perspective, the data collected are rich and each country is able to exchange and interchange experiences and recommendations, complementing and learning from each other, increasing the overall knowledge gain.

2 Methodology for Data Collection

The data collection activities during the 1st round of pilots were based on observations, interviews, focus groups, questionnaires, learning diaries, teacher diaries from students and teachers as well as technical discussions on the project development among the consortium partners. The data collected during the eCraft2Learn action are divided within 3 stages of collection: pre-pilot sessions, during pilot sessions and post-pilot sessions (see Figure 1)

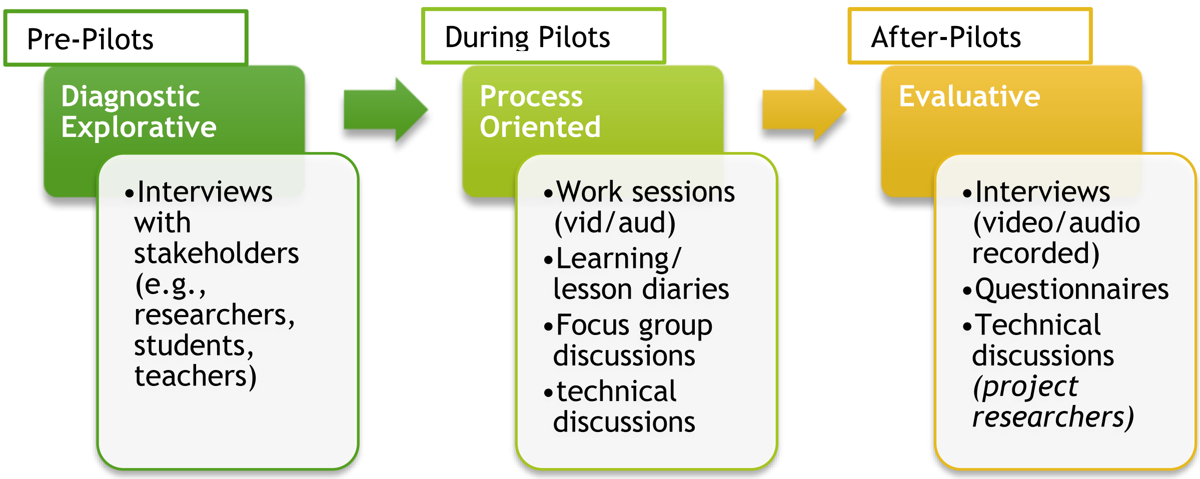

Figure 1. Stages of data collection during the eCraft2Learn action

The Pre-pilot sessions – diagnostic and explorative data, included interviews with different stakeholders of the project (e.g., researchers, teachers, students) in order to explore their views on the usage and application of technology to the classroom and informal settings. The results of the analysis of these data are out of the scope of this document (see for instance D2.1, D3.2 M5, D4.1 and D4.2 for a description of the analysis and results of the pre-pilot diagnostic and explorative data collected). The assumptions made from the diagnostic and explorative data were put to practice during the pilot sessions and to some extend evaluated through the after-pilots data collection. This deliverable focuses on the analysis of process oriented and evaluative data to build recommendations for improvements on the ecosystem built from the diagnostic and explorative data.

2.1. Process Oriented Data Collection

During the 1st round of pilots, these data included observations (with video, audio recordings) of the working sessions during the pilots as well as learning diaries and teacher diaries.

- **Observations.** Participants' observation is a traditional method of sociology and cultural anthropology. During the 1st round of pilots, observations involved the pilots participants while they were performing learning activities and interacting with each other within the eCraft2Learn learning ecosystem. The observations provided a qualitative understanding of these interactions. The goal of observations within the pilots was to identify the practices that the participants undertook while developing a task through the craft- and project-based pedagogical approach within the eCraft2Learn learning ecosystem. The observations were also valuable to identify problems and possibilities for improvement within the eCraft2Learn ecosystem. *Observations took place during the pilots' sessions.* The mechanism used to record the observations is given in Annex I.
- **Learning diaries.** *This research tool was used after each pilot session* for gathering data from the student for activities evaluation. The learning diaries included open-ended questions prompting the students to briefly recapitulate on the difficulties and successes of the working day. See Annex I for the template of the learning diaries used.
- **Lesson diaries.** *This research tool was also used after each pilot session* for gathering data from the teacher/instructor perspective on the activities of the pilots. The idea was to collect the teacher's or instructor's views on how the students were progressing with their projects or tasks within the eCraft2Learn learning ecosystem. See Annex I for the template of the lesson diaries used.
- **Focus group discussions.** *This research tool was used in the middle of the pilot period* in Finland and Greece. The idea was to gather together some of the teachers participating in the pilots in the formal context to discuss a specifically how the pedagogical approach together with the technological tools fitted into their work experience. This also served the purpose of a participatory design workshop where the teachers gave feedback and their impressions on the tools presented through the UUI. The guiding questions and topics of this activity are given in Annex I.

- **Technical discussions.** During the 1st round of pilots the project researchers engaged in a series of discussions related to the development, implementation and on-going deployment of the technical core as well as the pedagogical core of the project. The topics of these discussions varied including the updating the observation data mechanism (pedagogical perspectives), UUI accessibility and user-friendliness, RPis issues, scenarios deployment reports, and so forth.

2.2. Evaluative Data Collection

These data also included interviews (video, audio recorded) alongside questionnaires at the end of the pilot period.

- **Interviews.** Teachers and students participants provided their opinions and views on the pilots activities through semi-structured interview containing a set of pre-defined question. The pre-defined questions for the teachers semi-structured interviews were developed to take into account several pillars including expectations, perceived social, skills and cognitive impact of the activities, ecosystem (school support), UUI, gender issues and drop out (see the semi-structured interview guide in Annex II). For the students, the semi-structured interviews looked at how the students experience during the pilot activities was when going through the 5 stages pedagogical process, and what their reactions to this process were (see Annex II). This was directly linked to elicit the personal involvement and emotional details shown in each project that the students took part in during the pilots activities. During the interview, the structure was kept flexible so that the participant was free to elaborate on each topic and the interviewer supported the exploration of relevant topics. The idea was to capture the personal meaning and an emotional involvement (such as satisfaction, frustration, etc.) of the participants in the pilots activities. *The interviews took place at the end of the pilot round period* (after they had completed the lessons/projects).
- **Questionnaires.** Questionnaires, as a set of structured open- and closed-ended questions, were administered to students at the end of the pilot round (after they had completed the lessons/projects). The aim was to get a quantitative gauge of the students’ views and opinions regarding the pilots’ activities and projects that they developed. See Annex II for the questionnaire developed to obtain student feedback on their experience during the pilots.
- **Technical discussions.** After the pilot period, the technical discussions that the project partners engaged with included considering the UUI tools used for each pedagogical stage, the importance of sharing from the perspective of the teachers, and so forth.

Table 2 shows the data collection method applied to each context according to the participant type.

Table 2. Data collection methods, participant type and context of collection

	Feedback collection method	Participant type	Context	No. of instances
PROCESS ORIENTED DATA	Observations	Students teachers	Formal education	FIN 31 | GR 8
			Informal education	FIN 3 | GR 8
	Learning diaries	Students	Formal education	FIN 83 | GR 112
			Informal education*	GR 167
	Lesson diaries	Teachers	Formal education	FIN 8 | GR 47
			Informal education	FIN 2 | GR 37
	Focus groups	Teachers	Formal education	FIN 1 | GR 1
EVALUATIVE DATA	Interviews	Students	Formal education	FIN 9 | GR 2
			Informal education	FIN 4 | GR 4
		Teachers	Formal education	FIN 5 | GR 2
			Informal education	FIN 2 | GR 3
	Questionnaires	Students	Formal education	FIN 29 | GR 20
			Informal education	FIN 10 | GR 23
PROCESS + EVALUATIVE	Technical discussions	Project researchers	Technical/pedagogical development topics *(computer mediated communication)*	40+ *(topics discussed)*

Note: In Finland, student diaries were not analysed from the informal settings pilots deployment as it was noticed that students were not providing rich feedback based on the used forms (i.e., students were answering the learning diaries' questions with single words or not at all). From this experience it is emphasized the role of interviews as a data collection method with young children.

3 PEDAGOGICAL CORE – RECOMMENDATIONS FOR IMPROVEMENTS BASED ON COLLECTED DATA

The eCraft2Learn ecosystem pedagogical core is based on the craft- and project-based approach to STEAM education, putting forward 5 stages: ideation, planning, creation, programming and sharing (see D3.1).

In regards to the pedagogical processes embedded in the eCraft2Learn learning ecosystem, several observations, interviews and questionnaires were made and collected during and after the 1st round of pilots in Greece and Finland. The results of the collected data are listed below.

3.1. Data Collected in Greece – Pedagogical Aspects

A qualitative summary of the observations, interviews and questionnaires in Greece extracting the pedagogical aspects is given below.

- **Ideation and planning stages.** Athens pilots provided a lot of hands-on activity in a real “making environment” with a lot of trial and error, rotation in the roles of the students, good collaboration; students were also noticed frequently to take initiatives to change their initial plan/design. The methodology was focused more on the process of making than the final product, which offered valuable opportunities for learning; however, inspiration through pre-developed scenarios was needed in this 1st round in order to help students see the main functionalities and the available tools and to start imagining their own more (or not) complex projects. Hence, the ideation stage was inevitably implemented in the development of their own variants of the proposed scenarios in this 1st round.
- **Creation and Programming (and the eCraft2Learn pedagogical approach).** In general, students and teachers followed the eCraft2Learn methodology adjusted to students’ needs and implemented variants of projects based on students’ interests. However, the methodology was not followed in a strict serial way; students often while programming came back to creation for improving their artefact and continued again with programming; or while creating their artefact came back to planning making new choices and altering their initial plan and so on. Students have made their own transparent artefacts almost from scratch using open source technologies, DIY techniques, and hands-on activities in an authentic making environment (the “white box” paradigm). However, in few cases some “black boxes” were found necessary. For instance, the AI block in the Snap4Arduino in order to achieve the voice recognition (listen then…but if error…) was provided as a pre-developed block; the students and the teachers had just to copy and paste the AI block. Alternatively, in the case of the circuit (L293 chip) that we used to support the rotation of two small motors in the robotic car, the wiring diagram of the L293 was given ready to use. In tasks like the above ones, students can use generic “black boxes” in order to construct a technically robust robot or to program complicated but interesting things (i.e. voice recognition).
- **Sharing.** Sharing took place in the lab through presentations made by one student from each group in the end of each pilot session. Students are provided also opportunities to present their projects to the public in the Athens Science Festival. During the 2nd round of pilots sharing should

be enhanced through tools built-in the ecraft2learn UUI that will allow students (and teachers) to share their projects with broad communities of makers. Teachers and students need space to upload pictures and videos or showcase the current state of their work.

- **Teacher as coach - scaffolding**. The teachers thought that the worksheets[2] for students were important. The worksheets help mainly the students follow the 5 stages without revealing answers. In few other cases, teachers used their technical guidelines directly in the class to dictate students' work instead of leaving them to follow the student worksheet, which was written in a way to encourage students' initiatives, development of variants, and self-directed work.
- **Supporting teacher's role - OERs.** Teachers frequently ask for links to useful resources (i.e. exemplary projects, easy to start with projects, guidelines for teachers, worksheets for students, lesson plans, experiences from other teachers), for instance resources that help them explain to the students the breadboards ensuring that do not mechanically make the connections. Supporting materials help teachers feel more confident and better prepared no matter if other needs emerge as well that require additional exploration or co-exploration (with the children).
- **Detailed instructions.** Teachers feel comfortable with precise and clear step-by-step guidelines on how to progress with projects or activities. It can be concluded that the lower the experience of the teachers on programming and making, the higher the appreciation of 'step-by-step' guidelines.
- **Teacher's role transformation.** Transformation of teacher role is always a challenging task. We have seen most of the teachers acting as real coaches during the pilots. Only in few cases teachers were observed to act as instructors either giving some lecture or substituting students in their work especially with some circuits' assembly and programming tasks.
- **Adapt to teachers way of working.** Teachers at school are used to explicitly outline the learning aims and goals of each activity. This holds also for any eCraf2Learn intervention. A sustainable implementation of eCraft2Learn activities can be fostered if the value of such activities can be provided and the learning goals explicitly named and targeted towards the fulfilling of possible set criteria.
- **Proving success.** Connected with outlining the aims and goals of learning activities, teachers recommend to have some prove that the intervention or learning succeeded in some way or other. Teachers are increasingly under pressure of justify i.e. teaching, students performance,

[2] Worksheets to assist with the development of students projects has been created as part of the OERs of the project (this work is part of WP3 T3.3, D3.3).

possible costs and implementation into the general curriculum. Thus tools to support analysis of the learning might be valuable for some teachers.

3.2. Data Collected in Finland – Pedagogical Aspects

A qualitative summary of the observations, interviews and questionnaires in Finland extracting the pedagogical aspects is given below.

- **Pedagogical model.** All five stages from the pedagogical model were observed during the project work. Students were working iteratively in these stages, starting from ideation and planning and after experiencing issues with first created and programmed prototypes going back to ideation and planning.
- **Ideation and planning stages.** During the first round of pilots in formal settings, teachers introduced problems from curricular subjects, from where students could start ideating and planning their projects. No examples were shown to students of how a project and its solution could look like. Although this provided an opportunity to innovate personal ideas, some student teams were struggling with generating ideas where and how they could combine electronics into their project plans. A list of possible sensors and actuators (taken from D3.3 M9) was given to students to scaffold the ideation and planning stages. In general, the ideation and planning stages took relatively much time when starting the projects if no schedule about the project duration was given to students. Knowing the time limits helped students to steer their work after the first initial plans to start the creation and programming. It was also observed that the ideation phase is highly important to launch students interest and motivations: once they were able to follow up their own idea, they seemed to be highly motivated. Doing their own 'thing' is essential when launching these projects.
- **Creation and Programming.** Some student teams tended to spend a lot of time on handcrafting activities (e.g., using cardboard, playdough, recycled plastic bottles, etc.) as they wanted to build very detailed creations. With a gentle push from the teacher, students started testing their electronic components before they actually built everything ready. Agile prototyping, where an idea is tested in an early stage without spending too much time on creating something to the final shape, was seen to be characteristic for an effective team during the pilot sessions.

  What is more, few student teams were postponing the work with electronic components and programming as they did not feel so familiar or confident with the electronics. An important question lies, how can we engage all students to test and try out the electronics and programming? Teacher's role to encourage and support students to freely try and test without the fear of failure can play an important role. In some instances, it was observed that the teachers also suggested to the students to distribute the labour of work so that each student in a group is responsible for one task. For example, one teacher distributed the roles as follows "during this session Sarah will wire all electronics and in the next session Judith will have this role". Students also needed more specific instructions for each lesson, especially at the beginning when learning the basics about electronics. With enough information provided students could progress more autonomously without so much hesitation. This also allowed teachers to use their time more effectively for the whole class, instead of spending excess time with one team only.

- **Sharing**. Sharing happened in multiple ways: documenting the whole process or documenting only the final achievement at the end of the project task, sharing their progress or final achievement with other students' teams in the class or with other teachers that came to visit the class, curious to witness what was happening. Some students teams were sharing what they had learnt about electronics and programming with other students teams in the same classroom. This demonstrated collaborative work and peer-learning through sharing expertise by peer-helping when struggling. In two student groups the teacher encouraged students to document their work as a learning diary (blog). This was kind of a continuous sharing of the process. The teacher could use these blogs as a tool for assessment as well.
- **Collaborative work.** Students used each other's strengths when working in teams. There were students who had previous experience on programming, therefore they took the lead on the programming activities but also provided help for other team members or even in other teams in the classroom. Student team sizes were ranging from 2 team members to teams of six students during the first round of pilots. In one school, all student teams were smaller than in the other (having 2-4 students per team). It was observed that a smaller team size made the work more effective and students were also more on-task.
- **Creativity and *making***. Students did not like to sit and listen to a normal lecture, instead they enjoyed when they actually had the possibility to *make*, build and create. Moreover, the technical concepts seemed to be understood better if students built their projects at the same time while learning theoretical aspects - the teacher employed scaffolded discussions to foster reflection of the students' learning. Students also appreciated to be involved in projects where they could bring open solutions as they could use their creativity.

- **Characteristics of well-performing teams in inquiry-based learning.** During the sessions some teams were progressing faster and more effective than other teams. These teams invented and tested a lot of ideas in early stages which led to improving their original concepts and reaching more advanced creations. Generation of multiple ideas was a sign of a creative team as well and these teams came up with multiple, creative solutions to emerging problems or issues. Active collaboration between the team members where all students participated in the discussions and changed ideas also promoted good performance. In addition, well-performing teams had a clear distribution of labour. Indeed, students in these teams could include in their process all five stages (ideation, planning, creation, programming and sharing) at the same time. Furthermore, usually in the effective teams the team members used the strengths and interests of each student and could work in a flexible manner. In case well-performing teams were stuck in the process, these teams did not hesitate to ask help from teachers or other student teams.

- **Supporting teacher's role as coach**. In the discussions after pilot sessions, teachers were highlighting the importance of having guidelines or instructions for students for programming, electronics and 3D printing in order to lessen the need for teacher instructions and to support students to become more autonomous. During the 1st round of pilots open educational resources (OERs) were created to answer these needs. In addition, teachers felt they needed training to use the tools and applications developed or deployed in the UUI, as new concepts are introduced and used during the students' projects. It was observed during the pilots (and also confirmed during interviews with teachers) that the teachers will not intake into their practical teaching activities a new didactical tool (such as the ones put forward through the eCraft2Learn learning ecosystem) if they are not familiar with the tool and are confident in using it.
- **Curriculum activities vs eCraft2Learn ecosystem**. Teachers were also mentioning that the methods used in the project (electronics and programming itself) cannot be "glued on top of the curriculum", thus then they won't stay in everyday use in the classrooms. Some lessons that were run with the eCraft2Learn ideology were taking more time than teaching the same content with more traditional methods. Few teachers that were not part of the eCraft2Learn project were questioning the decisions to spend so much time for one topic only. How can teachers justify the use of these methods? What is the impact these projects actually give for student learning?

3.3. Pedagogical Topics – Computer Mediated Communication

In this section, highlights and examples of email exchange among project researchers on pedagogical topics are shown.

- On the incorporation of concepts of **self-regulated learning, self-reflection and self-awareness** into the eCraft2Learn pedagogical core and to be supported by the UUI

R1: " *We need to think about even more carefully when implementing reflection and self-regulation to this eCraft2Learn 5 phases (ideation, planning, creation...etc) the role of reflection and guidance for students (as well teachers) to regulate their own learning processes and activities in EACH five phases - we should have reflection and regulation in all of them. Sometimes the confusion about how to support the activities of five phases versus reflection and regulation of their own learning activities."*

R2: *"So far, there has not been any clear cut between the stages, learners mix and match as they proceed with the development of the task. Could it be that using SRL they can see the importance of each stage and reflect on the goals that each brings?"*

R3: *"I feel it quite challenging to make specific suggestions for each stage in relation to SRL as the same activities and questions can be used in (almost) all the stages. How would you differentiate for example the teaching methods for each phase of SRL in each stage? "*

Discussion among researchers (Rs) continues regarding the best approach to incorporate SRL into the pedagogical core.

- On the incorporation and usage of **learning analytics**

R1: *"I would also love to know about learning analytics … I believe I asked for the same thing a couple of weeks ago .. I imagine it's one of the super important topics for innovation management (WP2) as it impacts the way we support learning, organise teacher preparation and also might use it for others questions … it's also a nice thing as it goes beyond the UUI and in the future would be a bridge to other education related systems … "*

R1: *"do we have somewhere a list of what data are actually collected for 'learning analytics' purposes?"*

R2: *"Yesterday some of you wished some slides related to the learning analytics. As an attachment you will find the English version of the pp presentation (as pdf) we used here in Joensuu during the teacher training."*

R2: *"This is the reminder for the Learning analytics demo."*

Discussion among researchers (Rs) continues regarding issues surrounding learning analytics implementation in the eCraft2Learn ecosystem

- On the importance of the **sharing stage**

R1: *“For once they [the teachers] consider the sharing as the most important point from the pedagogical concept when it comes to functionalities (though I have to say that since they are teachers, I assume that the previous parts are simple for them, since it's their day-to-day job). However, sharing should be a major point the the UUI when it comes to the teachers opinion. In this context it was mentioned also Moodle and Mahara (I think this is an ePortfolio tool). One teacher was mentioning that the networking would be essential for him. Thus emphazising the sharing and networking and communication would bring an added value to other simple websites.”*

R2: *“These are very good points made about the UUI and its functionalities - a timely feedback indeed since our partners at LNU are working on putting forward a native Sharing tool to be included there. A point to clarify, though, what type of sharing was the teacher referring to? (this is a topic that was briefly discussed earlier, started by Christian, on the different types of sharing that there may be). It seems that the teacher was talking about 'sharing' the UUI as a plug in to other LMSs?”*

R1: *“Teachers seemed to be very keen to share some step-by-step guiding activities; including objectives and learning aims; they seek for support, exchange of ideas, inspiration and experiences made. Of course they would like to combine it with already existing systems they are using like i.e. Moodle.”*

- On **supporting material** for teachers/students when working with electronics/programming

R1: … *"Actually the reason I am going through your documentation is the ‘support finder’, i.e. the tool that scans various databases for materials that might support teachers and / or students (including translation) and know we were wondering about the knowledge they bring to these workshops … So maybe the tutors can also capture their impressions on how much the participants already knew (e.g. did you really have to explain a circuit with an LED or did they understand the controlling of a service motor quickly etc).”*

R2: *"The idea of a support finder would be for a great use and help for the teachers. At the moment I feel teachers (also students) need a lot of support about the technical side of the project. However, some part of the issue comes from the insecurity even though there would be enough knowledge! By providing some information, we could encourage the teachers and students in the process."*

R1: *"The challenge will be to not replicate work of other Internet repositories. We imagine it somehow like a layer on top of databases such as Instructables or Thingiverse. We would also like to include other databases such as create-education - to increase the usefulness - , however at the moment they are*

not offering an API or subscribe to an 'open data' strategy … But once we have a working prototype it will be easier to convince other to come on board.The confidence issue is an interesting remark - I was just thinking that we could try to harvest not only for 'technical information' but also for 'experiential reports from beginners' … just to communicate 'You can do it !
*And it's actually an idea ** is working on - how can we take thingiverse or instructable instructions and transform them into something which fits the purpose of a particular workshop or the plans of the teacher … In the end we couldn't provide guidelines for every possible combination [of lesson plans] but enabling teachers to create their own personalised collage of 'making steps' (supported by mini-guidelines) and integrating them into their own (lesson) plans …"*

- On ideas for **3D printing** in teaching and learning

R1: *"So for starters the example is good to do it once but then the most important thing is to get teachers understand how much they can change this lesson plan and adapt it … "*

R2: *"As I have noticed here in Finland, this could be a good way to motivate girls to engage with the 3D printer. At the moment, they have been very happy with crafting using recycled and other physical materials to build their projects. No so much excitement demonstrated towards the 3D design, however. Boys have demonstrated more interest in 3D design/printing, on the other hand. They will probably like this tutorial as well!*

R3: *"It could be that the student can get the ideas demonstrated in the tutorial to build their own design and use it in their project. If they wish, they could follow the entire process to get similar results to the ones in the tutorial. But as you said, **, this could be a very flexible way of getting creative with the 3D printer - hopefully, we can get this message across to the teachers. "*

R1: *"I guess it's quite normal to see differences in preferences when it comes to 3d-printing, electronics and wearables … But then maybe we can have 2-3 options (specially for older kids) who don't need that much handholding, e.g. Sonya's link with 3d printing snowflakes is also very intriguing … wouldn't be my thing, but then to me it adds to a bigger picture where teachers could realise that there are multiple ways to create 3d / 2d models and that they or the students can combine them in creative ways .."*

3.4. Recommendations for Improvements – Pedagogical Aspects

Based on the data collected and presented previously, the recommendations for improvement of the pedagogical processes of the project are extracted below:

I. **Teacher's role.** Based on the experience of the teachers during the 1st round of pilots and the importance to start the transformation of the teacher's role to that of a coach, it is recommended that during the 2nd round of teacher training, teachers should be invited to reflect on their role during 1st round of pilots, to what extent their role was transformed to that of a coach, what went well and what went wrong and so on. They should be also invited to contribute to the participatory planning of the 2nd round of pilots recalling their experiences so far. Furthermore, in order to support teachers to acquire appropriate skills and to run an eCraft2Learn project with more confidence, a Teacher's Quick Guide was created as a part of the teachers' crafts- and project-based manual (see D3.4). The quick guide provides systematic instructions on how to design and implement an eCraft2Learn project successfully. It suits for both pre-service and in-service teachers and helps to identify and put in practise the main principles of an eCraft2Learn project-based teaching and learning methodology.

II. **Team collaboration.** During the pilots, a smaller team size resulted in more effective work among all students in the team as students were observed working more actively and having less off-time. In contrast, in teams of six members for example only three members were actively participating in the work. However, it is understandable that each student is different and this observation does not apply to all cases. Furthermore, Haapaniemi & Raina (2014)[3] suggest that younger students might benefit better from participating in smaller groups. In addition, if project based learning is not familiar for the students smaller group size is recommendable. Based on these reasons, it is recommendable that teachers try to implement their projects with different sized teams and make observations for what is the optimal number of students in one team for each particular student group.

III. **Sharing.** When discussing the eCraft2Learn project sharing stage during the teacher interviews, teachers noted it would be good for the students to present their initial ideas after the ideation and planning stages. Thus, student teams could get valuable feedback from their peers for the creation and programming phases as other students could see the ideas differently 'outside of the

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[3] Haapaniemi, R., & Raina, L. (2014). How to build a group that learns — The manual of pedagogic thriving [Rakenna oppiva ryhmä — Pedagogisen viihtymisen käsikirja] (in Finnish). *Jyväskylä: PS-kustannus*

box' and perhaps have already experience and knowledge to share with others. Presenting and explaining the ideas and plans can in turn improve their thinking and reveal students something crucial for the plan to be successfully created already in an early stage. In addition, giving constructive feedback for others is an important skill students should learn. It is then recommendable to include sharing activities in different phases of the project progress, not only after completion of the project outcome.

IV. **Curricular integration.** One issue of deciding to run a lesson using the eCraft2Learn learning ecosystem was to find a justification for the extra time spent on the projects when comparing eCraft2Learn methodology with methods that are more traditional. The eCraft2Learn projects do not only teach students the use of electronics and programming skills, instead the students familiarize with and improve a wide range of transversal skills creativity, teamwork, problem solving and communication. The projects have a multi- or interdisciplinary perspective when students are combining arts, physics, hard crafts and social studies in their work in a flexible and natural way. In fact, teachers mentioned that in their opinion, many different skills are needed next to the scientific knowledge: crafting, programming, making, understanding of art, etc., thus cooperation between teachers of different subjects should be targeted in order to successfully complete projects. Teachers could plan even longer projects if they would collaborate. Perhaps same student groups could have the same team of teachers, which would foster the projects to be carried out easier when lessons could be switched between teachers more easily. It could also serve as a justification for the subject matter and scheduling issues when teachers are trying to balance between the reality of the classroom and the demands of the curriculum. It is understandable, however, that support from the school administration to facilitate the curricular integration is fundamental in achieving the multi- and interdisciplinary nature of the projects developed through the eCraft2Learn learning ecosystem.

V. **Self-regulated learning.** Based on the internal discussions regarding the development of the pedagogical core, it is also recommended to integrate aspects of self-regulated learning, self-reflection and self-awareness on each stage of the pedagogical approach. These concepts should also be discussed with and understood by the teachers working with the eCraft2Learn learning ecosystem. (See D3.4)

4 Technical Core – Recommendations for Improvements based on Collected data

The technical core of the eCraft2Learn learning ecosystem is based on the following tools (see D4.2 for detailed explanations on the selection of tools and implementation of the technical core):

- Raspberry Pi 3 (RPi3) as the experimental development platform,
- One or more Arduino boards connected with a variety of electronic components, which constitute the designed artefact,
- A basic set of software tools integrated with the other parts of the eCraft2learn technical core (i.e., UUI, educational extensions, learning analytics, etc.)
- A 3D printer used for preparing customised physical components integrated in the creation-programming-sharing workflow. This integration represents another innovative aspect of the eCraft2Learn action.

This core is recommended for its cost effectiveness when there are no PCs available - the RPis are credit card size computers will all the practical functionalities of a normal PC, but only costing a fraction of the price. Nevertheless, when computers are available the digital platform of the eCraft2Learn learning ecosystem, the unified user interface (UUI), is accessible through Chrome browser, and RPis are not needed. When deploying and using the technical core during the 1st round of pilots, qualitative process oriented and evaluative data were also collected from the perspective of the technical core in order to provide input and feedback for improvements.

4.1. Data Collected in Greece – Technical Aspects

A qualitative summary of the observations, interviews and questionnaires in Greece extracting the technical aspects is given below.

- **RPi3 issues.** RPi - based laboratory setup was a bit slow but adequate and covered the needs of the scenarios of the 1st round, except 3D design where VNC solutions / Laptop based solutions were used instead. Based on this, the experimental setup to keep for 3D printing (and design) tasks during the pilots has been reassessed. More specifically:
    - The RPi - based laboratory setup was a bit slow but adequate and covered the needs of the scenarios of the 1st round, except the 3D modelling tasks. On the other hand, the 3D modelling and printing tasks performed drastically better through VNC (Virtual Network Computing) connections from the RPi3 workstation units to a laptop hosting the 3D modelling and printing software.

- o The need for a second 3D printer to better cover the "hanger" for printing of the teams is apparent. Indeed, a 3D printer every 4 student teams should be a nice ratio and do not omit to have a conventional (2D) printer as it is a valuable tool while project development.

- **Programming (hardware and software)**. Snap4Arduino is a bit tricky and unstable but covered most cases of scenarios, except ultrasonic distance sensor related tasks. Stand- alone artefact behavior programming on the artefacts is possible but not as straightforward as with the Ardublock tool. Hence, most of the artefacts have been developed using the Snap4Arduino and the Ardublock programming environments. These tools have been thoroughly investigated during the 1st round pilots.

  - The Ardublock tool, compared with the Snap4Arduino, was more efficient and stable for stand-alone artefact behaviour programming and easier to use. On the other hand, Ardublock has a serious drawback as it provides limited interoperability options with other educationally meaningful environments.
  - Snap4Arduino was a bit tricky to setup but covered most cases of scenarios. Attention must be paid as some trivial sensors (like the HC SR04 ultrasonic distance sensor) are not fluently supported yet by the community. Thankfully, during the project, various improvements to Snap4Arduino platform have been made, leading to a more stable version. The latest enhancements of the Snap4Arduino (web version) tool so as to be hosted by eCraft2Learn owned servers, will provide better stability and freedom during the second round pilots. It must be mentioned though that this tool, especially in its web based version, seems not to work fast enough all the time, mainly due to the low read/write speed that the microSD card of RPi3.

- **Components.** Many artefact architecture variants are possible. For example, Arduino-based only autonomous artefacts could be created or RPi-based only artefacts as well. Of course, Arduino-based artefacts consume 2 to 10 times (depending on the rest of the components) less energy than their RPi based counterparts. So which configuration to keep depends on the needs of each specific application. For instance solar power bank assisted artefacts is better to use Arduinos only so as to have greater autonomy. In cases when we use tablets (or smartphones) in the scenarios, the development of RPi based artefacts would be the most preferable solution supporting tablet – artefact interaction.

- **Time management.** It is not surprising that during the 1st round of pilots things took longer than expected. More specifically, gluing and wiring components together, programming and 3D printing required more time and effort than what was initially expected and thus, the overall goals should be modest enough and exhibit a high degree of progressiveness, modularity and scalability. Projects of the second round is expected to have more 3D designed/printed parts and to exhibit higher degree of (remote) interactivity and autonomy, but still should remain comparatively simple, in order to be realistic to implement.

4.2. Data Collected in Finland – Technical Aspects

A qualitative summary of the observations, interviews and questionnaires in Greece extracting the technical aspects is given below.

- **RPi3 issues.** The SD cards in RPis get corrupted or broken quite easily. RPi3 also tended to freeze frequently during usage.

- **Power feeding issues with Arduino.** One issue observed when students were creating projects where they combined a lot of long wires or multiple sensors and actuators to the Arduino. Student noticed that the sensors did not work anymore or the Arduino board did not respond. Another issue was the situation when students were combining multiple sensors together and sometimes the sensors did not give consistent values although each component would work well individually.

- **Supporting the circuit creation and programming.** One request from a teacher was to have a simulation environment where students could test the electronic circuits and program codes without having to own any physical equipment. ¨

- **Issues with Snap4Arduino when using laptops.** During the pilots a problem was observed where Snap4Arduino could not communicate with Arduino when the school laptops were used instead of Raspberry Pis.

- **3D printing.** 3D modelling was an interesting activity for most students. Although, students did not always understand how complex their models can be or how much time it takes to print their model in the size they were imagining it to be. Thus, students' expectations were not met and this sometimes led to a drop of motivation, especially if the student did not understand what had caused the printing failure. There would be great learning opportunities after unsuccessful printing trials to go through the 3D printing more in detailed by for example looking at the different printing settings in Cura.

- **Setting up the devices and components (time management).** In both of Finnish formal pilot sites the devices that were used to set up the technical environment were stored in a separate classroom or storage where they were brought in the correct classroom before each pilot session. During the interviews, teachers pointed out that in their school the devices had to be taken to two different classrooms during one week. Assembling and disassembling these devices took a lot of time from the class, especially when the class was only 45 minutes long.

4.3. Technical Discussions – Computer Mediated Communication

There has been a great deal of email exchanges on technical matters between the partners. Some have focussed on **feasibility and design issues** such as teacher customisation of the UUI, whether the UUI could **support timer alerts to prompt the students to reflect in their work progress (self-regulated learning, self-reflection and self-awareness)** and if so how to do it without disturbing the users. Discussions have also ensued on the core components of the technical core including whether **Chromebooks could be used instead of Raspberry Pis**; as well as on automatic data collection and unobtrusive tracking of students digital trace when using the UUI, such as what type of **data can be collected by the UUI** and by the tools for use by the **learning analytics**.

Discussions on the **programming related aspects** have included the reporting of network bandwidth limitations when using the developed educational extensions and AI blocks for Snap! and Snap4Arduino environments including speech recognition and image processing. A related topic of discussion has also been which versions of Chrome on the Raspberry Pi can run the AI extensions. In addition, the consortium has discussed the general appearance, accessibility and user experience with the UUI with topics such as how **translated versions of the UUI could be created** and how well Google Translate can fulfil this need, how logging in should work, the naming of the pilot site options, how to deal with logging into the UUI if not at a pilot site, integrating the OER resources, providing a unified style across the UUI and resources, and much more[4].

Furthermore, **bugs have been reported both via email and the Github issue tracker** (see Fig XX). Examples include problems installing the Chrome extension needed for Snap4Arduino to communicate with Arduinos, a UUI bug that only occurred in Firefox, a styling bug that caused some pages to be nearly unreadable, incorrect version of resources was being displayed, and much more.

[4] In the first months of the project there were very many email discussions about which tools to include in the eCraft2Learn ecosystem and their strengths and weaknesses (D4.1 and D4.2).

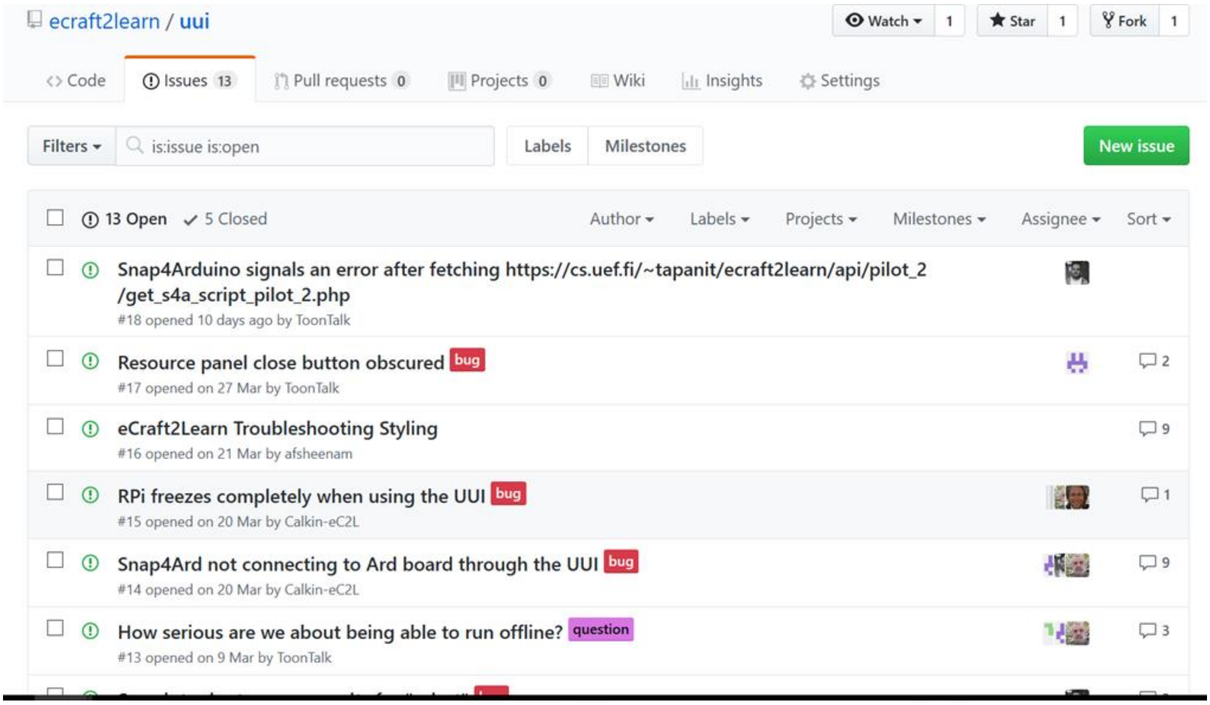

Figure 2. Bugs reporting outlet in GitHub

4.4. RECOMMENDATIONS FOR IMPROVEMENTS – TECHNICAL ASPECTS

The recommendations for improvements on the technical aspects of the project will be presented from the perspectives of the hardware (physical platform) and software (digital platform) separately.

4.4.1. TECHNICAL CORE – PHYSICAL PLATFORM

I. In order to get the **school laptops to support Arduino** or to find the Snap4Arduino to communicate with the laptop's USB ports, it is recommended to always use the Chrome or Chromium browser. In addition, a special procedure needs to be done to install the extension for Chrome or Chromium. Instructions for this procedure can be found from the UUI under the Educational Resources - Troubleshooting - eCraft2Learn components. Though, sometimes this won't solve the problem. We observed that Windows 10 supports the extensions better than for example Windows 7. Windows devices require drivers installed for the system and it cannot be done without administration rights. Thus when using laptops/PCs instead of RPis, it is recommended to use Unix-like computers because they include the required drivers in the kernel.

II. In order **to optimize the management of time** to carry out an eCraft2Learn project in formal settings, it is recommended that the eCraft2Learn technical core (RPi, Arduino board, monitor, keyboard, mouse, etc.), when it is used instead of PCs/laptops, is set and kept in the same place throughout the development of the projects. The experiences gained during the 1st round are to be used to finalize the time schedule and the content for the scenarios of the 2nd round, for both teachers' training and pilots with students.

III. For **remote communication** with the artefacts being created, WiFi links can be used. This solution requires Raspberry units and exploits their built-in radio interface to provide access through a simple python script or VNC. This method, although not the most efficient, is very simple to implement, and thus, has a great pedagogical value. The alternative of using WiFi shields for Arduinos can be trickier for the young students to apply.

4.4.2. Technical Core – Digital Platform

One important issue is related to the open and free tools in the unified user interface (UUI). When these tools require that the user needs to create an account and login the process might become hard to manage for the target group. This has been identified as a major problem in Stages 1 and 2. As result, tools in these stages will be addressed by tools implemented by the consortium. Issues with tools in stage 1 and 2 of the UUI representation of the pedagogical core were pointed out by teachers during focus groups discussions. Furthermore, the focus group discussions also provided feedback on the usefulness of the tools presented through the UUI and how they could be improved.

I. Ideation

The ideation stage has been powered in the UUI through the insertion of Google docs as a tool for sketching and ideating. The rationale for Google Drive being an ideation tool was that for those who are already familiar with Google docs it is a great way to create documents (with text, photos, drawings, tables, etc.). However, one critical issue with Google tools is that a user account is needed in order to access the service, and it is less appropriate for those not familiar with those tools. This may not cause major problems for learners in the age group of 16 – 17, however, for the age group of 11 – 15 the login process can be a threshold. Another problem noted with the use of Google tools is that it is not trivial to collect data from the activities of the learner working with a Google doc through the eCraft2Learn digital platform.

Recommendation for improvement. In order to tackle these issue, to re-think the idea of fostering imagination and to provide a more user-friendly solution than Google Drive during the eCraft2Learn Ideation stage, the implementation of a native ideation/planning tool is recommended. By native tool we mean a tool, which is developed for the UUI. Thus, any third-party tool such as Google Drive is not considered as a native tool in UUI. A native search tool that returns videos and pictures appropriately related to the keywords used could foster the children's creativity and imagination by displaying visual information on the searched topics.

II. Planning

For planning, the UUI has used Trello. This tool provides an easy to use web application designed for collaborative project management. In Trello, the work is divided into boards, and each board consists of several lists (or cards) that represent different stages of the work or different tasks. However, although Trello is a powerful tool, from Trello it is not possible to collect data from the students and push it to the learning analytics system.

Recommendation for improvement. In light of the issues mentioned above, for the planning stage the introduction of a native tool is recommendable. A native TODO tool where the students can plan tasks and assign them to a certain student is proposed. The app should also show the whole progress of the planned tasks for each group member. The planning tool aims at helping the learners to better organize their ideas. The native tools for ideation and planning have the marked advantage of being easily integrated with eCraft2Learn's data analytics system (see D3.4).

III. Creation

The creation stage has been only powered by the 3D design tool TinkerCAD. However, during the 1st round of pilots it was observed (and confirmed via teachers' interviews and focus groups) the need to have an electronics circuit simulator to assist with the creation process of the students.

Recommendation for improvements. Adding TinkerCAD Circuits simulator to the tools offered for Creation is recommended. In this tool designing DIY electronics and simulating the designs can be done. Note that the Circuits is a part of the TinkerCAD application that allows the learners to design DIY electronics and simulate the behaviour of their design. This application has built-in support for Arduino UNO R3 microcontrollers and has a long list of different electronic components including different type of sensors, outputs and actuators. TinkerCAD Circuits can also generate a "component list" when the design is finalized. Similar to TinkerCAD 3D Design it is possible to share the designs with classmates and teachers, although the sharing platform is not Thingiverse and is based on sharing direct links to invitees. Those who have the access link can collaborate in the design process by making changes to the design. "Circuits" also includes a code editor for developing in native Arduino language. The editor includes many different libraries and a debugger. The debugger provides tools to setup break points in the code and watch the variables during simulation. Furthermore, the TinkerCAD Circuit Designer can be used to encourage students to create things on their free time even without having an Arduino at home. This program is recommendable to be accessible through the UUI to answer the request of a circuit simulator from students and teachers. In addition, it is also possible to use the software when giving some task for the students as homework. Students could test the possibilities at home and come with possible solutions into the classroom.

IV. Programming

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 recommend for most purposes 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 has the disadvantage that there is no web version and we cannot collect data for learning analytics from it. In situations where the only computational devices are Android tablets and phones then we recommend MIT App Inventor and Pocket Code. For projects relying upon open live data sources NetsBlox is a Snap! variant that supports access to open data. The Arduino IDE is much more difficult for beginners to learn and master but is well-suited for advanced programmers.

Snap! is an open source blocks-based programming language supported by the University of California, Berkeley and SAP. 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 either control an Arduino interactively or to generate a script that is compiled and run independently on the Arduino. Like all blocks-based languages students using Snap! are presented with a semantically organised palettes of program components as differently shaped coloured blocks. 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.

AI 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.

For situations where a fast reliable Internet connection is available to the computing devices (e.g. Raspberry Pis or laptops) then ***we recommend the speech input and output AI extensions***. For contexts where students can register for free API keys from either Google, IBM, or Microsoft then the image recognition extensions are recommended. The image-based machine learning extensions work well on nearly all laptops and workstations. The audio machine learning extensions is recommended in nearly all contexts since it can be used by any device that runs the Chrome browsers.

V. Sharing

At the moment under the sharing stage, the UUI is providing Thingiverse which is an open maker community where anyone can share their own digital design files. This website allows students to showcase their projects not only inside their schools but also all over the world. During the observations and discussions with teachers it was evident that sharing of this kind only is not sufficient for the pedagogical purposes as sharing can consist of sharing the whole process of making as well.

Recommendation for improvement. One suggestion to meet this need is to implement a learning diary tool. The UUI could automatically save the different work that is done by the students in the earlier stages. For example, the picture that students create in the eCraft Plan tool could be saved to this diary. Students could also upload other pictures and write text to add to their diary. This tool would allow students to record their progress. As a result, their eCraft2Learn journey would be saved from the beginning until the end with all the different phases of a student work. Furthermore, teachers and students need support to present and share their result outside school environment as well, for instance presentation to another school, a video, Facebook entry, etc. Hence, it is recommendable to explore the possibility to support different kind of sharing (e.g., sharing among students/teachers within educational contexts and sharing with the open community) through the UUI.

5 USABILITY PERSPECTIVE RECOMMENDATIONS

We base our analysis of the data from a user experience perspective rather than usability since user experience is better aligned with pedagogical and technical perspectives. Empirical data on the UUI is very limited and therefore the analysis takes a more general perspective.

The themes identified on which we build the data analysis are:

- Learning style
- Motivation
- Creativity
- Practical issues
- Organization
- UUI

In the following, we begin by give a summary of the identified crucial points and suggestions on how to address these. Then we give a more detailed summary of the data from the pilots in Finland and Greece.

5.1. On Usability Evaluations of the UUI

To conduct a complete usability evaluation, specific methodology is required. For instance, a heuristic evaluation requires the expert evaluator's extensive knowledge of the product as well as suitable design principles for these kinds of interfaces in general, and for the UUI specifically. A mixed methods approach combining user testing and interviews are suggested. Extensive data on user context, user utility, and task completion are preferable. The following considerations can serve as guiding points:

- The UUI tools are easier to use when not so many tools need a login as logging in takes too much time from the class and usually passwords are lost etc.
- The UUI needs to have an attractive design for the users.
- The added value of using the UUI – instead of using individual software and visiting single pages - needs to be explicitly clear to the users in order to ensure the sustainability of the site

In this deliverable we focus on identifying themes in collected the data and built our suggested course of actions on these.

5.2. Suggested Future Course of Action

There are several crucial points that can be brought forward from the empirical material. One of these are the two parties' (teachers and students) perception and judgment regarding their own learning and enabling technology. The teachers were unsure of their own knowledge and capabilities and needed a space to examine and discuss possible opportunities to use the UUI. This in turn made them think the level of knowledge needed being too steep for the students. The student themselves didn't think that they would understand anything prior to the study.

The study showed that technology anxiety was reduced afterwards; student confidence was higher and strengthen through seeing direct results of technology use. The students were proud of their work. Thus, introducing and using technology in a learning environment decreases potential anxiety towards the technology used.

The teachers' role as a coach in tandem with the students' ability to freely choose methods based on needed knowledge and skills, as well as the available ensemble of technologies and knowledge resources, enabled flexibility and problem-solving skills. Hence, this freedom was seen, both from the teachers' and students' perspective, as fostering creativity as well as introducing self-regulating learning of the students. In turn, this meant that teachers could focus more on coaching instead of direct intervention on the learning activities. Skills such as team building and collaboration is an inherent part of the self-regulated learning in teams.

Both teachers and students were in general eager to perform and learn, as long as they saw benefits in doing so. Focus on planning and working iteratively based on the plan was a key factor for the students to achieve self-confidence.

Specifically addressing the UUI, the respondents were all teachers within fields of natural sciences from programming/engineering to physics and chemistry with most teachers having 10+ years of experience of teaching. Most agreed that the proposed model presented in the UUI could be applied to their teaching activities, but only depending on specific activities. The stages presented in the UUI were all seen as relevant and there was no clear consensus if some stages were more important than others whereas all stages were interconnected. The stages ideation, planning and creation were seen as crucial and needed iterative work to results in a good result. Most of the teachers also agreed that the model could fit into the curriculum, but these would need to be revised to enable full incorporation since the curriculums are usually based on courses/specific learning rather than projects. There were clear benefits, which could be derived from the pedagogical model proposed. The main areas identified were skills related to team building, learn by doing, creativity and problem solving. Seeing direct results were seen as something positive. The UUI in itself gave enough functionality, based on the stages involved, but half of the respondents also felt that more functionality was needed. Even though the search utility, information and collection of technologies were reported as useful, more of these utility functions were needed. This includes code explanations and analysing tools, guides of safe use of technology, more educational oriented software as well as a more enriched way of sharing learning. The UUI also helped the coaching process when using specific technologies and organizing projects but there was scepticism whether this could actually be implemented in any classroom.

In conclusion, there are some areas that could be improved and important areas identified are the following:

- **I.** There should be support of using these tools in the curriculum. One suggestion is that information about how this has been done can be introduced in the UUI.
- **II.** Introductory and educational material and examples to introduce the concepts and technologies could be presented in the UUI, which would lessen the initial burden. Examples are showcase of earlier work or interviews with teachers that has used the platform (and its UUI). In addition, showcasing different kinds of solutions could help teachers see how they could fit this pedagogical approach including its technology use into their current teaching pedagogy and teaching subject.
- **III.** A framework of how to iteratively work with the five stages of the pedagogical approach could help facilitate the students' achieving the learning goals.
- **IV.** A place to share ideas in the UUI and gather thoughts from the teachers' perspective could prove fruitful and help new teachers grasp the process.
- **V.** The coaching teacher could give extra focus on facilitating the division of work between students in a team to foster teamwork as well as learning amongst members of a student team.
- **VI.** Showcasing the end results could be a key factor to increase interest in the project. Presenting content that displays both the learning process, learning history, as well as the result, is an appropriate way to go.
- **VII.** Extra tools for explaining and analysing code could be implemented in the UUI.
- **VIII.** Guides for safety regulation in relation to the technology used should be available in the UUI.

The above-mentioned areas would change the technology disposition, facilitate both the teachers' and students' learning, communication and collaboration skills as well as facilitate motivation and commitment. Most could be done through "showing the way" by adding extra content in the UUI.

6 CONCLUSION

This report presented the recommendations for the eCraft2Lear action ecosystem improvements. The document addressed the improvements from the pedagogical core and technical core of the ecosystem as well as the cores usability perspectives. The recommendations were based on the qualitative analysis of the data collected during the 1st round of pilot in Finland and Greece (period November 2017 – March 2018).

ANNEX I – PROCESS ORIENTED DATA COLLECTION MECHANISMS

A. Observation form

Observer:	
Pilot site:	
Event date/time:	
Pilot session:	

Notes regarding the context and the resources

Number of teams:	
Number of teachers/coaches:	
Number of students in attendance:	
Pilot session duration:	
Educational resources used by the teachers/coaches (i.e. videos, web-links, print-outs, etc.…):	

Overall workshop impressions:

Needs emerged (if any):

Group #…………………………… (to be completed for each group- group 1, 2, 3….)

The 5 stages	**Did the students go through this stage today?**		**Comments/Interesting quotes:**
Ideation	Yes		
	Yes, but to a limited extent		
	No		
Planning:	Yes		
	Yes, but to a limited extent		
	No		
Creation:	Yes		
	Yes, but to a limited extent		
	No		
Program:	Yes		
	Yes, but to a limited extent		
	No		
Share:	Yes		
	Yes, but to a limited extent		
	No		
	Accomplished?		**Comments** related to the projects (i.e. extensions, technical difficulties encountered)
Project/Artefact construction	Yes		
	In some extent		
	No		

Notes:
- It is completed by one project member
- Language: English

B. Students' learning diary

Name:……………………. Team:…………………….. Date:…………….

1) **What did you like the most today?**
2) **What did you like the least today?**
3) **Did you learn something new today? If yes could you please refer to what you learnt?**
4) **Do you have a new project idea that you would like to have implemented by the end of pilots?**
5) **The collaboration among the team members was today....**

None | Poor | Fair | Good | very good

Notes:

- The diaries are completed by the students in the end of each session.
- In Greece it is more convenient for the students to complete paper-based versions of the diaries directly after the session. Paper-based version was also used in Finland
- The questions will be in Greek /Finnish
- The diary has the following form:

Diary ...../...../.....

NAME:............ TEAM:............

What did you like the most today?

What did you like the least today?

1

Do you think that you learnt something new? If yes could you please refer to what you learnt

Do you have a project idea that you would like to have implemented by the end of pilots?

The collaboration among the team members was today....

very poor | poor | fair | good | very good

2

C. Teacher/Coach lesson diary

Team……………………… Coach……………………………. Date …………………………..

1. Please complete the following table reflecting upon what happened today in the eCraft2Learn workshop?

Project description:	
Number of hours spent on the project so far (approximately):	
Current state of the project:	
Tools (hardware and software) and materials that have been used/tried out so far:	
Describe briefly your role today:	
What resourses (if any) did you use to support the learning process today? *(i.e. images, videos, documents, etc ……)*	

2. Please complete the following table reflecting upon what happened today in the eCraft2Learn workshop?

The 5 stages	**Did the students go through this stage today?**		**Comments:**
Ideation	Yes		
	Yes, but to a limited extent		
	No		
Planning:	Yes		
	Yes, but to a limited extent		
	No		

The 5 stages	Did the students go through this stage today?		Comments:
Creation:	Yes		
	Yes, but to a limited extent		
	No		
Program:	Yes		
	Yes, but to a limited extent		
	No		
Share:	Yes		
	Yes, but to a limited extent		
	No		

3. **How was the collaboration among the team members?**

   No collaboration / poor / fair / good / very good

4. **To what extent are you satisfied with the level of students' engagement today?**

   Not at all/ very little / somewhat / to a great extent

   Comment: ……………………………………………….

5. **To what extent are you satisfied with the progress made by your team today)?**

   Not at all/ very little / somewhat / to a great extent

   Comment: ……………………………………………….

6. **To what extent are you satisfied with the creativity demonstrated by your team today?**

   Not at all/ very little / somewhat / to a great extent

   Comment: ……………………………………………….

7. **Did you learn something new from your interaction with the students today?**

   …………………..

8. **In the following scale….(1 = traditional teacher/ 5 = coach) ….where do you place your role in the workshop based on today's experience?**

   1 2 3 4 5

Notes:

- The diary is going to be online and will be completed by the teachers after each pilot session.
- Language: English

D. Semi-structured focus group discussion guide

Questions to pedagogical Model:

- Is the model applicable to your day-to-day teaching? Can you integrate it well?
- Do you see some stages more relevant than others?
- Do you think you and/or your colleagues can apply it to other subjects as well?
- Does the model fit within your curriculum?
- Where do you see the benefit of the pedagogical model?
- Is there anything you could think of that would support you by implementing the model?

Questions to UUI:

- Does the UUI provide sufficient functionalities?
    - Which ones do you find most useful?
    - Are there some more functionalities that you would like to see included? If so which ones?
- Does the UUI provide sufficient guidance towards a curated set of tools?
- Is the data analysis helpful for you?
- Does the UUI help you in your teaching?
    - If yes, how?
    - If no, why not? What needs to be changed?
- ...

Notes:

- This is not aimed at being a classical "usability testing", rather using the teacher to ask him/her for functionalities:
- The topics here are for guidance only – they should be expanded as the focus group conversation progresses

ANNEX II – EVALUATIVE DATA COLLECTION MECHANISMS

A. Semi-structured interview guide - teacher/coach

Team………………………......................... **Coach…………………………….**

Date of Interview …………………………..

A) Framing the setting

1. *** Can you describe and explain your projects (or group) and the respective setting?
   Please make sure that you cover following questions:
   Number of students:
   Age of students:
   Topic covered:
   Materials used:
   Description of classroom environment or setting:
   Number of teachers/coaches supporting the projects in your team:

B) Pillar - Expectations

1. * What were your expectations when you started the workshop?

2. * Were these expectations met? Pl. explain why they were met, not met or even excelled.

C) Pillar - Impact social, skill and cognitive

1. *** Was there any change you were observing compared to the way they usually work or interact? i.e.
   a. In the way how the students were working?
   b. In the way how students were interacting with each other?
   c. Behaviours of single students that changed?
   d. Group dynamic of the class/group?

2. *** Were the students in the position to drive their own learning? i.e.:
   a. ... choosing their own topics/projects
   b. ... choosing their own materials they would like to use
   c. ... determine their own timing

d. ... finding own ways to solve their problems

e. ... choose if and with whom they would like to do their project

3. *** Did the workshop influence

    a. ... your own way of teaching or your own perception of your role as a teacher and coach?

    b. ... your perception of learning, skills and soft skills?

    c. ... your own hesitation/acceptance/fear towards technology?

    d. ... your view on future needs and abilities that students need to gain?

    e. ... the self-esteem of the students?

    f. ... each students individual development – if so how?

    g. ... any other influences that you possibly observed?

4. *** In your opinion, what do the students learn from the projects on a cognitive, social and soft skill (like teamwork, self-steered learning, ...) level?

    a. Did the projects increase the students' level of digital competency like:

        i. Programming (yes/no)

        ii. Making and/or Crafting (yes/no)

        iii. Electronics (yes/no)

        iv. Problem solving (yes/no)

        v. Internet search (yes/no)

        vi. Any other, if so which: ________________________

b. Did the projects decrease the students hesitation/fear towards technology?

c. Did the projects allow the students to be creative?

e. d. Did the projects allow students to develop own solutions for issues they faced? Did the workshop offer opportunities for co-learning? Did you learn something new from the students?

D) Pillar - ecosystem

1. ** In your opinion: What would be the ideal conditions to implement projects like these, in terms of:

    a. The school environment (rooms, facilities, ...)

    b. Regulations and rules (ie. school curricula)

    c. Support from other teachers or headmasters or

    d. Support from parents or local community incl. ?

    e. Financial support

    f. Any other?

1. ** Were you able to observe the different stages of the pedagogical framework

(1. Ideation - Exploring the world;

2.Planning a project;

3. Designing and building computer-supported artefact;

4. Programming the built computer-supported artefact;

5. Sharing.)

... and was this framework useful to you? Explain why or why not.

2. ** Have the projects facilitated interdisciplinary learning?

3. * Was the pilot recognized by other teacher colleagues, the headmaster or the parents. If so, what was the reaction?

E) Pillar - UUI

1. What advantages do you see in using the UUI?

   a) it provides a central place for project management

   b) it provides guidance towards a curated set of tools

   c) it is a means to gather data for learning analytics

   d) it is a nudge towards using our 5 pedagogic stages

   e) any other: ____
2. Have you observed any issues using the UUI?
3. Are there any improvements for the UUI that you would suggest? If so, which ones?

F) Topic Gender

1. ** Did you observe any differences between male and female students (i.e. in the interacting, the learning with the UUI or the project itself)?

2. Do you see the projects as a way to increase the share of girls/women in science and technology?

3. Would you launch different projects for male or female study groups? If so, why?

G) Topic Drop- out

1. *** How many students from your team dropped out of the workshop and do you know why these students dropped out?

B. Semi-structured interview - student

1. **Can you tell us a bit about your workshop experience?**

    a. In which projects did you involve? (Topic)

    b. Who was in your group? (number of girls and boys)

    c. How did you work in the groups? (ie.

        i. Did you seperate the work, or did all members work a the same?

        ii. How did you decide how the end-product should be designed?

        iii. Who did the programming?

        iv. Did you have issues and problems and how did you solve them?

        v. What did you do when you faced issues and where did you find solutions?

        <comment: depending on the project, try to understand how the pupils interacted with each other, if they were innovative and found creative solutions.>

2. **What were your expectations for the eCraft2Learn workshop and where your prior conceptions/expectations met? Why or why not?**

3. **Who was facilitating/coaching you? And how did he/she support you?**

4. **What did you like most during the projects?**

5. **What did you like least?**

6. **Do you feel now more comfortable than before the project with**
   a. ... programming
   b. ... to make and craft things
   c. ... to work with electronics
   d. ... to tackle problems and issues
   e. ... to find solutions for issues that we faced
   f. Any other, if so which: ________________________

7. **Can you tell us more about your work in the open project?**

8. **Would you like to continue working with these equipment in some other projects?**

9. **Can you imagine working in future in this area?**

C. Students' questionnaire

How did you like the workshop?

not at all | not a lot | I liked it | I liked it a lot

During the workshop I was able to:

	YES	A BIT	NOT AT ALL
… be innovative			
… be creative			
… do the things the way I preferred			
… test and try out			
…to plan and coordinate with others			
… to share with others			

I feel more comfortable than before to …

	YES	A BIT	NOT AT ALL
… programme			
… make and craft things			
… to work with electronics			
… to tackle problems			
… to find solutions for issues that we faced			

Any other, if so which: _______

During the workshop I liked most:

During the workshop I liked least:

Thank you