eCraft2Learn

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

Deliverable D5.6

Claims validation, final conclusions and recommendations

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EXECUTIVE SUMMARY

This report addresses responses to the claims initially made regarding the educational value of the eCraft2Learn learning initiative. These claims are firstly that “*The eCraft2Learn ecosystem is useful as a supporting backbone to the craft- and project-based learning pedagogy*” and secondly that “*The eCraft2Learn ecosystem can foster the development of 21st century skills in youth*” (see in DoA the section “*Pilots and evaluation” page 22*). The second claim is three-folded and include the sub-concepts that “*The eCraft2Learn ecosystem can foster Creativity*”, “*The eCraft2Learn ecosystem can foster Critical Thinking*”, “*The eCraft2Learn ecosystem can foster Problem-solving*” and “*The eCraft2Learn ecosystem can foster Collaboration Skills*”.

Several qualitative and quantitative data sources were used for the validation of claims, including Student Diaries, Teacher Diaries, Observation Forms, Teacher Interviews, Student Interviews, Final Student Questionnaires, Interesting cases, and Communications from parents (testimonials) collected during the intervention realised at four pilot sites of the project, as well as during conferences and exhibitions. The analysis results of the qualitative as well as the quantitative data sources conclude that the initially made claims are valid. This report further formulates conclusions and recommendations regarding the future use of the ecosystem as a whole.

The report is divided into four parts. The first part defines the main claims regarding the educational value of the eCraft2Learn learning initiative and provides relevant literature for each claim. The second part briefly describes the methodology and tools used for the validation of the claims. The third goes into details regarding the analysis of results gained by way of the evaluation tools used during the educational intervention. The analysis is separate for each claim and each evaluation tool is individually considered for the evaluation of each claim. The fourth part details the conclusions and recommendations of the analysis as a whole.

1 INTRODUCTION

This report addresses responses to the claims listed below, which were initially made regarding the educational value of the eCraft2Learn learning initiative and formulates conclusions and recommendations regarding the future use of the ecosystem as a whole.

The claims

1. The eCraft2Learn ecosystem can foster Creativity,
2. The eCraft2Learn ecosystem can foster Critical Thinking,
3. The eCraft2Learn ecosystem can foster Problem Solving,
4. The eCraft2Learn ecosystem can foster Collaboration Skills,
5. The eCraft2Learn ecosystem is useful as a supporting backbone to the craft- and project-based learning pedagogy.

A mixed scientific method to evaluate the eCraft2Learn claims on the educational value of the eCraft2Learn learning initiative was adopted, including different kinds of qualitative and quantitative instruments that allowed for the triangulation of sources of data and perspectives (students, teachers and parents).

The research data for the validation of claims came from classroom/session observations, the questionnaires, diaries and the interviews with students and teachers in Greece and Finland (see Appendix 1 and D5.4, D5.5), statements received by parents of the participating students as well as additional documentation received by the participating teachers regarding the educational value of the eCraft2Learn learning intervention. Briefly, the following tools were used for the collection of data from the pilot sites. For a more detailed description, please see D5.4 section 2.2.

1. Student Diaries,
2. Teacher Diaries,
3. Observation Forms,
4. Teacher Interviews,
5. Student Interviews,
6. Final Student Questionnaires,
7. Narrative Reports from teachers (post pilot completion),
8. Parent statements and comments.

The validation of the claims is based on the impact measurement findings of D5.4, on classroom episodes and descriptions that are described in D5.5, and additional data analysed in this report emerging from students, parents and participating teachers which cross-verify the findings, and so contribute to the final validation of the claims made.

This report contributes to the project development and exploitation as it validates the claims related to the educational value of the eCraft2Learn ecosystem opening up the avenue for wider deployment. The conclusions and the recommendations that are provided in section 5 can be useful to teachers and other stakeholders with interest in deploying the eCraft2Learn initiative in additional educational settings.

More precisely Section 5 offers teachers, teacher trainers, educators, educational advisors and policy makers' recommendations that are underpinned by evidence from the pilot studies in Greece and Finland. It identifies key characteristics of important lessons learnt and gives practical examples based on observations made in the formal and informal pilot sites in Greece and Finland. Recognising that every education system is unique, it does not make prescriptions about specific educational system, but provides a set of recommendations on how STEAM teaching and making experiences can be brought together through the eCraft2Learn learning ecosystem. Focus is specifically placed on the role of the teachers/educators in the eCraft2Learn ecosystem in order to support young learners (13-17 years old) to develop 21st century skills (creativity, critical thinking, and problem solving and collaboration skills) through their engagement in hands-on, craft and project-based experiences. Researchers in educational sciences can build on the suggestions and the recommendations that are made for further exploring the educational paradigm suggested by the eCraft2Learn project and promoting the making culture into formal and informal education settings.

2 Presenting the Five Major Claims

The main claims initially made regarding the educational value of the eCraft2Learn learning initiative are:

1. The eCraft2Learn ecosystem can foster Creativity, one skill out of the 21st century skills in youth,
2. The eCraft2Learn ecosystem can foster Critical Thinking, the second skill out of the 21st century skills in youth,
3. The eCraft2Learn ecosystem can foster Problem Solving, the third skill out of the 21st century skills in youth,
4. The eCraft2Learn ecosystem can foster Collaboration Skills, the fourth skill out of the 21st century skills in youth,
5. The eCraft2Learn ecosystem is useful as a supporting backbone to the craft- and project-based learning pedagogy.

What are 21st century skills? There is no single widely-accepted definition of "*21st century skills*". Arguably, this is to be expected, given the diversity of agendas held by different educationalists, policy makers, employers, teaching unions, and higher education institutions. According to Silva (Silva, E. 2009), there are hundreds of descriptors of the skills set, including life skills, workforce skills, interpersonal skills, applied skills, and non-cognitive skills.

One of the largest research ventures currently underway is the Assessment and Teaching of 21st Century Skills (ATC21S, 2013). The stated purpose of this international collaboration among academics, governments and three major technology companies is to empower students with the right skills to succeed in the 21st Century workplace (ATC21S, 2013). An initial objective of the ATC21S project was to develop clear, operational definitions of 21st century skills. Researchers began by conducting what is probably the most thorough recent review of the literature in this field. They analysed the definitions developed and used by eleven major organisations, including the Partnership for 21st Century Skills (2013) in the United States and the Lisbon Council (2007) of the European Union.

The ATC21S researchers concluded that 21st century skills can be grouped into four broad categories: (i) ways of thinking, (ii) ways of working, (iii) tools for working and (iv) skills for living in the world (Binkley, M. et. al. 2010). Within these categories, they identified ten skills as encapsulating all others and accommodating all approaches. In particular, problem-solving and ICT operations and concepts, are listed by all organisations (Table 1). Communication, collaboration, and information literacy (the ability to mine new information and interact constructively with it) are also frequently cited (Suto, I. et. al. 2014).

Table 1. Definitions of 21st century skills (based on table in Suto, I.et. al. 2014)

21st Century Skills reviewed by ATC21S				
Skills	**Partnership for 21st C Skills (2013)**	**Lisbon Council (2007)**	**ISTE NETS (2013)**	**ETS iSkill (2013)**
Creativity	✓		✓	✓
Critical Thinking	✓		✓	✓
Problem Solving	✓	✓	✓	✓
Collaboration	✓	✓		✓

Within the context of this report, we based our analysis on the parameters of 21st century skills investigated in literature, in particular with reference to the above analysis. As a result, the analysis focused on creativity, critical thinking, problem solving and collaboration skills.

2.1. Creativity

Creativity is often described as a thinking skill or at least as an important aspect of thinking that can and should be fostered (Wegerif, R. et. al. 2004, p. 57). According to Binkley (Binkley, M. et al. 2012), the operational definitions of creativity and innovation cover how learners deal with new and worthwhile ideas. These include an open attitude to the ideas, the knowledge and skills to create these ideas, as well as to work on the ideas and innovate, tackling failure in the process (Gary Ka-Wai Wong et al. 2018). Creativity has been growing in importance as a key 21st century thinking skill (Wegerif, R. et. al. 2004, p. 57). For example, Web 2.0 technology enables users to produce and share content in new ways: User-generated content creation and "*remixing*" (Lessig, L. 2008) become creative practices that challenge the traditional relationships between teachers and students in providing information and content for learning and the role of the "*school book*" (Erstad, O. 2008) . One of the problems with the discussions around creativity has been the often simplified and naïve notions and romantic conceptions of the creative individual (Banaji, S. et. al 2007), without clear specifications of what this skill area might entail. Thus, it has proved to be difficult to assess students' creativity. (Binkley, M. et. al. 2012, page 31).

A number of subjects in the school curriculum of various countries ask students to make various kinds of products. (Sefton-Green et. al. 2000). These might include paintings in art class, creative writing, performance in drama, recording in music, videos in media studies, and multimedia "*digital creations*" in different subjects. (Binkley, M. et. al. 2012, page 38). In a review of the connection between technology, learning, and creativity, Loveless (Loveless, A. 2007) shows how technology allows children to produce high quality finished products quickly and easily in a range of media that provide opportunities for creativity. Loveless (Loveless, A. 2007) argues that to foster creativity in the classroom, teachers need to create a social atmosphere in which children feel secure enough to play with ideas and to take risks. Since creativity can involve every sense (sight, hearing, touch, smell and taste) and is almost infinite, it defies precise definition. In particular in ICT education, Manches (Manches et. al. 2017) refer creativity as "*generating ideas and strategies as an individual or community, reasoning critically between these and producing plausible explanations and strategies consistent with the available evidence*" (Agogi et. al. 2014, p.8). Indeed, when children engage in programming activities, they have opportunities to solve computational problems in creative ways and develop a computer program (Mishra et. al. 2013) Debugging activities in programming also allow children to think creatively about strategies to refine their ideas.

In a systematic review of the impact of the use of ICT on students and teachers for the assessment of creative and critical thinking skills, Harlen (Harlen, et. al. 2003) argue that the neglect of creative and critical thinking in assessment methods is a cause for concern, given the importance of these skills for lifelong learning and in the preparation for life in a rapidly changing society. Their review documents a lack of substantial research on these issues and argues for more strategic research (Binkley, M. et. al. 2012, page 31).

Definitions of creativity and innovation are provided in (Binkley, M. et. al. 2012, p.38), included in the general idea of ways of thinking, together the three categories of skills under "*Ways of thinking*", knowledge, skills and Attitudes/values/ethics represent a push forward in the conceptualization of thinking. These skills emphasize higher order thinking skills, and subsume more straightforward skills such as recall, and drawing inferences. A major characteristic of these skills is that they require greater focus and reflection. While creativity and innovation can logically be grouped together, they originate in two different traditional schools of thought. Creativity is most often the concern of cognitive psychologists. Innovation, on the other hand, is more closely related to economics where the goal is to improve, advance, and implement new products and ideas. Measuring both can be quite challenging. The tasks require an interactive environment, but they frequently cannot be done in the short period of time allocated to a large-scale assessment, nor are there good benchmarks against which respondent output can be evaluated (Binkley, M. et. al. 2012, p.38). Furthermore, the level of creativity expressed by students might depend on the freedom provided in the programming requirements (Gary Ka-Wai Wong et. al. 2018).

In some other works in the field of education, creativity is often defined as creative potential (Barbot, B. et. al.; Runco, M. A. 2003) which is understood as the human capacity to produce original and valuable work that fits within particular tasks or domain constraints (Runco, M. A. et. al. 2012). By relaxing the requirements, students can demonstrate their creative thinking in developing the digital artefacts and programmes to achieve the goals (Denner, J. et. al. 2012). However, excessive freedom and flexibility can affect the creativity of students, because they might not be able to achieve the expected outcomes. Creative potential must be differentiated from creative achievements. In other words, creative potential is an ability to produce some kind of original idea or work, which means that it may, but does not have to result in creating products of objective creative merit (Gralewski, J. 2016). In this context, creative potential is connected with problem-finding and problem solving abilities, and provides a necessary, but not sufficient condition for any creative activity and creative achievements (Plucker, J. A. 1999). Considering the fact that children and young people very rarely generate products which, in the light of social assessment, may be considered as creative, teachers should take a main interest in the creative potential of their students, rather than their pursuit of creative achievement (Barbot, B. 2015; Kaufman, J. C.2009). Glăveanu (Glăveanu, V. P. 2011) points out that if we restrict creativity only to the product, then we can overlook what student’s creativity actually is, or what it may become in the future. On this basis, teachers’ focus on developing the creative potential of students, shaping their confidence in their own creative abilities and supporting creative activity, maybe in the future, result in their developing authentic creative products (Gralewski, J. 2016). However, it does not change the fact that children and young people are able to generate solutions that are surprising, unusual, using a fresh attitude to the problem, even though their general utility or social value is sometimes low (Glăveanu, V. P. 2011).

2.2. Critical Thinking

Critical thinking is a rich concept that has been developing throughout the past 2500 years. The term "*critical thinking*" has its roots in the mid-late 20th century. Michael Scriven & Richard Paul define critical thinking as the intellectually disciplined process of actively and skilfully conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action (Scriven, M. et. al. 1987)1. Classification of critical thinking and problem thinking in the same category as decision making is presented in the work of Binkley (Binkley, M. et. al. 2012). According to Gary Ka-Wai Wong (Gary Ka-Wai Wong et. al. 2018) critical thinking involves the knowledge, skills and attitudes to think systematically and evaluate evidence, make reasoned judgements and decisions, and articulate these through clear explanation and justification of the process.

[1] https://www.criticalthinking.org, retrieved 15/11/2018

In recent decades, a popular topic for research, debates, forums and conferences on the role of education is the need to help students develop critical thinking skills. Concern about the need to help students develop critical thinking skills has increased over the last decades. Students try to build a profile to face the job market and cope with the demands of 21st century society, which is characterized by rapid changes and advances not only in the technological aspect, but in social and economic matters where knowledge is critical for a nation growth (Crenshaw, P. et. al. 2011). For instance, The US Department of Education (Woo-Jeong, S. et. al. 2012), states that graduates do not have the thinking skills needed for a considerable number of job vacancies. Brookfield (Brookfield, S. 2005) explains that critical thinking is one of the major objectives of education since learning to think critically can help students resolve ambiguity and embrace or adapt to continuous social, cultural and technological change. In the literature on the nature of "*good thinking*" and how it might be taught, the term "*critical thinking*" is often used to describe competencies which seem to be applicable to teaching–learning in context but also to learning in many workplace contexts (Pithers, R.T. et. al. 2000), including skills of argument (Kuhn, D. 1991).

Important theorists, supporters and researchers on critical thinking defend its fundamental role in all different fields and knowledge domains, as well as in all life settings where human beings develop, such as work, education, family, friends, and community (Moseley, D. et al. 2005; Butler et. al. 2012). In the work of Liu (Liu, Ou L. et. al. 2014), critical thinking defined as in relation to the current challenge in education which is to prepare high-qualified people who are able to meet the demands of the labour market. Moseley (Moseley, D. et al. 2005) based on the outcomes of Zarei (Zarei, A. et. al. 2012) affirm that critical thinking and education are closely related and that it is urgent that education offer students the opportunity to develop skills, abilities and capabilities as well as have values associated to critical thinking and applicable to life outside the classroom. Also, Karbalaei (Karbalaei, A. 2012) argues that education is responsible for promoting students' critical thinking development. Similarly, Butler (Butler, H. 2005) based on the work of Liu (Liu, Ou L. et. al. 2014) states that critical thinking has received special attention from educators and higher education policy makers. For example, The European Commission (EC, 2007) argues that young people need to be prepared to enter the job market and engage in lifelong education not only for fostering personal growth but also for being able to adapt to rapid changes in the labour market. Besides, The Australian Higher Education Council (Chapman, E. et. al. 2010, p.105) in its educational policy states that all graduates regardless of their field of study must develop and demonstrate capacities for thinking critically, solving problems, selecting and handling information, having qualities such as intellectual curiosity and rigor, creativity and imagination, as well as ethical values like integrity and tolerance. The Colombian National Ministry of Education (MEN "*Propuesta de lineamientos*") includes critical thinking, among others, as generic skill for higher education.

According to Lye (Lye, S. Y. et. al. 2014) and Wright (Wright, G. A. et. al. 2012) part of programming through CT is critical thinking since children participate in the programming process. In addition to that children solving any computational problem requires constant judgement and justification of the process, from algorithm design to testing and debugging. Decision making throughout the different stages of programming requires critical thinking skills (Gary Ka-Wai Wong et. al. 2018). In particular according to Moomaw (Moomaw, S. 2012) if children can learn how to think more critically, they will create more feasible and comprehensive computational solutions to programming problems.

2.3. Problem-solving

The term problem solving means slightly different things depending on the discipline. For instance, it is a mental process in psychology and a computerized process in computer science. There are two different types of problems, ill-defined and well-defined: different approaches are used for each. Well-defined problems have specific goals and clear expected solutions, while ill-defined problems do not. Well-defined problems allow for more initial planning than ill-defined problems. Solving problems sometimes involves dealing with pragmatics, the way that context contributes to meaning, and semantics, the interpretation of the problem. The ability to understand what the goal of the problem is, and what rules could be applied, represents the key to solving the problem. Sometimes the problem requires abstract thinking or coming up with a creative solution (Schacter, D.L. et al. 2009).

Research during the last decade has shown how new social practices evolve due to increased use of new digital technologies, especially among young people (Buckingham, D. et. al. 2006). Such practices create re-conceptions of key skills, not defined from a systems level, but from the everyday lives of people in our societies. One example is research done on computer games and online communities (Gee, J. 2007), where problem solving is defined as a key component of such practices. Such experiences of problem solving among young people need to inform us in the way we design assessment tasks and define key skills. In the context of computer science and in the part of artificial intelligence that deals with algorithms (algorithmic), problem solving includes techniques of algorithms, heuristics and root cause analysis. In computer science area the approach to problem solving is often described as computational thinking (Grover, S. et. al. 2013; Israel, M. et al., 2015). Through a series of thinking processes and skills, the ultimate goal is to solve the programming problem by developing a computer program as a digital artefact. In addition to that, metacognitive skills and problem-solving skills can be developed because the “*solver*” can “*teach*” the computer how to solve the computational problem, while articulating their thoughts and observing the outcomes for improvements by programming the computer (Clements, D et. al. 1984). Children can learn how to solve problems by themselves, and collaborative problem solving can also occur during the coding process (Israel, M. et. al. 2015).

Another area of high interest concerns the way digital tools can support collaboration in problem solving, creative practices, and communication. There are many examples of how computer-based learning environments for collaboration can work to stimulate student learning and the process of inquiry (Wasson, B. et. al. 2003; Laurillard, D. 2009). Collaborative problem-solving skills are considered necessary for success in today’s world of work and school. Online collaborative problem solving tasks offer new measurement opportunities when information on what individuals and teams are doing is synthesized along the cognitive dimension. Students can send documents and files to each other and, in this way, work on tasks together. This raises issues both for interface design features that can support online measurement and how to evaluate collaborative problem-solving processes in an online context (O'Neil, H. F. et. al. 2003). There are also examples of web-based peer assessment strategies (Lee et. al. 2006). Peer assessment has been defined by some as an innovative assessment method, since students themselves are put in the position of evaluators as well as learners (Lin, S. S. J., et al. 2001). It has been used with success in different fields such as writing, business, science, engineering, and medicine (Binkley, M. et. al. 2012).

Problem-solving strategies are the steps that one would use to find the problems that are in the way to getting to one's own goal. Some refer to this as the "*problem-solving cycle*" (Bransford, J. D. et. al. 1993). In this cycle one will recognize the problem, define the problem, develop a strategy to fix the problem, organize the knowledge of the problem cycle, figure out the resources at the user's disposal, monitor one's progress, and evaluate the solution for accuracy. Human beings have developed physically or intentionally various techniques usually called problem-solving strategies (Wang, Y. et. al. 2010), like abstraction: solving the problem in a model of the system before applying it to the real system, Analogy: using a solution that solves an analogous problem, Brainstorming: (especially among groups of people) suggesting a large number of solutions or ideas and combining and developing them until an optimum solution is found, Divide and conquer: breaking down a large, complex problem into smaller, solvable problems, Hypothesis testing: assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption, Trial-and-error: testing possible solutions until the right one is found and various others.

2.4. Collaboration

Operational definitions of collaboration according to Binkley (Binkley, M. et. al. 2012) can be defined in a set of ways of working like, to interact effectively with others and in diverse teams, manage projects, guide and lead others, be responsible to others. Several important research initiatives have worked on collaboration. Çakir (Çakir, M. P. et. al. 2009) have shown how group participants, in order to collaborate effectively in group discourse on a topic like mathematical patterns, must organize their activities in ways that share the significance of their utterances, inscriptions, and behaviours. Their analysis reveals methods by which the group co-constructs meaningful inscriptions in the interaction spaces of the collaborative environment. The integration of graphical, narrative, and symbolic semiotic modalities facilitates joint problem solving. It allows group members to invoke and operate with multiple realizations of their mathematical artefacts, a characteristic of deep learning of mathematics. Other research shows how engaging in reflective activities in interaction, such as explaining, justifying, and evaluating problem solutions, collaboratively can potentially be productive for learning (Baker, M. J. et. al. 1997). Several studies have also shown how taking part in collaborative inquiry toward advancing a shared knowledge object can serve as a means to facilitate the development of metaskills (Child, S. et. al. 2015).

Collaboration has recently been identified as an important educational outcome in its own right, rather than just a means to develop or assess knowledge, which is learned through engagement and practice (Kuhn, 2015; Lai, E. R. 2011). Collaboration has been described as a skill that encourages learning mechanisms (such as induction, deduction and associative learning) to be enacted (Dillenbourg, P. 1999; Hunter, D. 2006). The NRC (2011) outlined several justifications for collaboration's status as a key 21st century skill. Researches show that collaboration has influential effects on student learning and knowledge retention (Fall, R. et. al. 1997; Rojas-Drummond S. et. al. 2003; Saner, H. et. al. 1994; Webb, N. M. 1993). It is claimed that collaboration has distinct advantages over individual problem solving because it allows for: an effective division of labour; the incorporation of information from multiple sources of knowledge, perspectives, and experiences; and enhanced creativity and quality of solutions stimulated by ideas of other group members (OECD, 2013). Similarly, collaboration has also been found to increase students' social competency (e.g. conflict resolution skills and use of helping behaviours) and academic self-concept (Ginsburg-Block, M. D. et. al. 2006).

Organisations, faced with the need to innovate, use collaboration to combine the potential and expertise of their employees (Knoll, S.W. et. al. 2010). This is linked to recent advancements in technology, which have opened up new opportunities for how collaboration can be enacted (Salas, E. et. al. 2008). The stated importance of collaboration means that appropriately defining its construct remains an important aim. The main issue here is that the notion of collaboration, although almost universally accepted as being useful for application in the classroom and beyond, is conceptually vague (Brna, P. 1998). Different frameworks of 21st century skills place collaboration as either a learning skill, an interpersonal skill (NRC 2011) or a way of working (ATC21S 2015). These frameworks have different conceptualisations of collaboration as a construct, and in terms of its interaction with other skills (Lai et. al. 2012).

Collaborative problem solving competency is the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution (Child, S. 2015). Each of the three emphasised aspects are important factors in the maintenance of collaborative activity. For a collaborative "*state*" to be constructed (Brna, P. 1998) there has to be a task where the achievement of the goal requires more than one person to pool resources. This view is shared by Roschelle (Roschelle, J. et. al. 1995), who broadly define collaboration as a "*coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem*". In another work Dillenbourg (1999) defines collaboration as "*a situation in which two or more people learn or attempt to learn something together*". The sharing of roles and responsibilities during collaboration closely relates to the concept of the joint problem space (Roschelle, J. et. al. 1995). The joint problem space implies that group members enter into a social contract with the joint aim of achieving a desirable outcome. In this sense, group members enter into a collaborative state (Brna, P. 1998) that has to be effectively maintained until the problem is solved, or the outcome is reached (Child 2015). Collaboration contains inherent flexibility of roles and responsibilities with regards to the various subtasks in achieving a goal (Lai, E. R. 2011).

2.5. eCraft2Learn Technical Ecosystem can Support the Craft- and Project-Based Learning Pedagogy

Marc Prensky urges to move from “*telling/lecturing*” to the “*new pedagogy of kids teaching themselves with the teacher’s guidance*” (Prensky, M. 2008). According to Paul Curtis, chief academic officer for the New Technology Foundation, the real educational needs are “*a new type of instruction that better reflects the goals we want each student to achieve, demonstrate, and document*” (Pearlman, B. 2006). Since 2001, the New Technology Foundation (NTF), based in Napa, California, has helped fifty-one communities to launch and implement 21st century high schools. The New Tech networks’ experience is that students work best, produce, and construct knowledge through project-based learning (PBL). The Buck Institute of Education, which shares the same rigorous PBL methodology as NTF, defines standards-focused PBL as “*a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks*” (Buck Institute of Education, 2003). Through projects, New Tech teachers are able to embed all the learner outcomes (content and 21st century skills) and assess against them. Learner outcomes are the same across all subjects and interdisciplinary courses. Projects have associated rubrics for content, collaboration, written communication, oral communication, critical thinking, and so on, and are all posted online for students so they can decide on their own whether to achieve basic, proficient, or advanced work. (Pearlman, B. 2010). In addition to that in Finland several development projects have been started aimed to develop the curriculum and technology education (Järvinen, E.M. et. al. 2000; Lavonen, J. et. al. 2004; Parikka, M. et. al. 2009). Moreover, many public and private institutions claim that there is a growing need for employees, who are able to think critically and also to solve a range of technological problems (Grabinger, R. S. 1996). The Finnish curriculum in 2004 emphasized the meaning of technology from the point of view of everyday life, society, industry and environment, as well as human dependence on technology. The students should be familiar with new technology, including ICT (information & communication technology), how it is developed and what kind of influence it has. Students’ technological skills should be developed through using and working with different tools and devices (Autio, O. 2015). Student-centred, project-based science (PBS) instruction requires greater inquiry and depth than traditional teacher-directed exercises, while supporting student learning through an authentic approach. Both computer technology projects and arts and crafts projects can support PBS instruction, although the former are replacing the latter as schools focus more on student computer technology skills (Tabatha, J. et. al. 2014).

On other studies there are findings that a person who completes all phases of a craft process (design, implementation, and evaluation) gains experience that strengthens and maintains the inner control ability of a human being (Kojonkoski-Rännäli, S. 1995). Crafts as a hands-on activity nurtures the makers’ creativity and problem-solving skills and offers them an opportunity to test their ideas and see them realized (Rönkkö, M.-L. et. al. 2015). In the material making process, the hands and the mind are engaged simultaneously (Lepistö, J. et. al. 2015). Hands-on activities support the development of the students’ comprehension skills and creativity as well as giving them an opportunity to experience the world and make conscious decisions based on that experience. It is an essential part of the students' intellectual and physical development (Sigman, A. 2008). However, the students must be allowed to experience both the anguish and the joy related to design and making, the slowness of the process and the elation of success. The craft teaching supports the students' development as responsible and active citizens in a versatile manner (Rönkkö, M.-L. et. al. 2016). Root-Bernstein (Root-Bernstein, R. et. al. 2008) have found that successful scientists participate in arts and crafts more than the general population with top-performers engaging in arts hobbies more than their peers. Arts and crafts promote pattern recognition necessary for scientific problem-solving; manipulative skills important to laboratory procedures; visual thinking needed for envisioning spatial problems; and observational skill development through drawing, painting, or modelling (Root-Bernstein, R. et. al. 2008; Root-Bernstein, R. et. al. 2013). Integration of various disciplines through craft work goes beyond that of integrating mathematics and science to include such fields as culture, communication, and the building of spatial and sequential thinking skills (Griffis, K. et al. 2006; Moseley, C. et. al. 2007; Rule, A.C. et. al. 2012). Craft-based assessment can bridge language barriers for English language learners or for those who struggle with written language (Gooden, K. 2005). In the primary grades, Rule and Zhbanova (Rule, A.C. et. al. 2012) used examination of ecological relationships of unpopular animals such as bats, skunks, snakes, and spiders with poetry and motivating craft-making of these animals to assist students in successfully developing humane attitudes. Both hands-on craft-making and use of computer technology to produce a science related product to evidence student learning are viable approaches that involve minds on learning and use of multiple skill sets (Tabatha, J. et. al. 2014).

Kampylis mentioned (Kampylis, P. et. al. 2010) that ICT has introduced new ways of creative expression, providing innovative tools, media, and environments that can contribute to the creative process and enhance the accessibility and availability of learning resources (Buckingham, D. 2007). The utilization of computer-based learning environments (CBLE) by primary-school students, inside and outside school, transforms the way they learn, leads to a multiplication of settings in which learning can occur, and provides new tools for learning (Kampylis, P. et. al. 2007, Kampylis, P. et. al. 2006). By using CBLEs, students have the opportunity not only to be collectors and consumers of information, but also creators and collaborators (Loveless, A. et. al. 2000). They have the means to externalize, share, develop, and refine their thoughts, ideas, and inspirations in ways that could not be accomplished with traditional tools (Kampylis, P. et. al. 2006). However, it is not the access to CBLEs that can enhance students' creative thinking but the potential of CBLEs for supporting imagination, production, originality, and value (Loveless, A. 2003). On the other hand Buckingham (Buckingham, D. 2007) argued that the everyday uses of ICT by children are mundane and not creative (Kampylis, P. et. al. 2010).

3 VALIDATION METHODOLOGY AND TOOLS

3.1. DESCRIPTION OF THE METHODOLOGY

A mixed scientific method to evaluate the eCraft2Learn claims was adopted, including different kinds of qualitative and quantitative instruments (methodological triangulation) collected by students, teachers and key stakeholders. The term "*mixed methods*" refers to the mixture of quantitative and qualitative data within a single assessment. The basic premise of this methodology is that such integration permits a more complete and synergistic utilization of data compared to doing separate quantitative and qualitative data collection and analysis (Jick, T. D. 1979, Flick, U. 2011, Kelle, U. 2008).

To answer the questions, several analyses were performed on qualitative data (19 teacher and 43 student interviews, 469 student diary entries, 113 teacher diary entries and 154 student questionnaires) as well as on quantitative data sets (student questionnaires, observation sheets, teacher diaries). The single analysis of this data provide valuable insights into the educational value of the eCraft2Learn learning initiative. Collectively, they allow for the extraction of similarities and differences, but also complement each other. The methodology we followed is based on this triangulation design which typically involves two phases; an initial quantitative phase, followed by a qualitative phase. In our case, we combined the qualitative and the quantitative data, and so using both data types generated results of claims regarding the educational value of the eCraft2Learn learning initiative. In this way, both the quantitative and qualitative data contributed to the outcomes oriented to each claim. We further explored the findings from the questionnaires through exploration of qualitative interviews with teachers and students as well as statements received by parents of the participating students regarding the educational value of the eCraft2Learn learning intervention, in order to better understand how the personal experiences of individuals line up with the questionnaire results. For the analysis of qualitative data we used the Chi-Square test when there was an adequate amount of data, Fisher exact test for 2x2 tables and its generalisation exact test for IxJ tables utilizing the multiple hypergeometric distribution. Special algorithms and software for computing exact tests for IxJ tables are widely available (Mehta, C. R. et. al. 1983). For certain analyses, specialized software is better than the major packages. The software that we used in all cases, including the specialised ones, is the trial edition of StatXact software, which provides exact analysis for categorical data methods and some nonparametric methods. Among its procedures are small-sample confidence intervals for differences and ratios of proportions and for odds ratios, as well as Fisher exact test and its generalizations for IxJ tables. It can also conduct exact tests of conditional independence and of equality of odds ratios in 2x2 tables, and exact confidence intervals for the common odds ratio in several 2x2 tables (Argesti, A. 2002; Argesti, A. 2007).

3.2. THE TOOLS

The evaluation tools used provided responses to the claims initially made regarding the educational value of the eCraft2Learn learning initiative and the educational value of the suggested learning intervention. It was equally important to receive feedback from the students in order to explore the extent to which they benefited from the eCraft2Learn learning intervention in relation to the development of the targeted 21st century skills. The tools offered an insight into the students' experiences and created opportunities for them to share their experiences with the eCraft2Learn implementation team through the use of questionnaires that take the form of a diary that is updated on a regular basis and include questions that can be easily answered by the students (e.g. What did they like the most? What did they like the least? Do they feel that they learned something new? What went wrong?). Questionnaires that offer students the opportunity to document their feedback were supported (if necessary) by focus group interviews, which allow the researcher to alleviate issues inherent in the questionnaires and can offer an insight into students' perceptions and experiences. Observations during teacher training sessions and pilots with students revealed useful information about the physical setting, the make-up of the individuals being observed, the interactions that take place and how to supports educational targets.

The tools used were student diaries, teacher diaries, observation forms, interviews with teachers, and interviews with students, final questionnaire filled in by students, interesting cases and communications from parents (testimonials). Several interviews were conducted with teachers and students, which are the basis for the qualitative data analysis at hand (January 2018 - May 2018). In addition, several "*short*" interviews during events were integrated into the data set, since valuable information could be extracted from this source as well (video clips). The transcript interviews were used to create 34 codes in MaxQDA qualitative analysis software. The data material was assigned to these codes and served as a basis to structure the analysis.

The quantitative analysis is based on student questionnaires, teacher diaries and observation sheets. As regards the student questionnaires, although there are several standardized published scales available that measure self-confidence, self-efficacy or related constructs, such as FSKN (Deusinger, 1986), FKK (Krampen, 1991), PALS (Midgley et al., 2000) and some sub-scales of PFK (Seitz & Rausche, 2004), none were suitable as they are for our purposes. Therefore, a tailor-made questionnaire for students was developed.

Due to the fact that the pilots allowed extensive adaptability to the preferences of each teacher, the study environment of the students and the ecosystem on the whole, we analysed each pilot separately. Thus, in total we have four analyses that were compared with each other. In addition, the student questionnaires were used to ensure consistent analysis (Greece and Finland). This way, we were able to identify differences and similarities, barriers and facilitators in comparison to the results achieved and to the interviews analysed. The collection of this data usually took place during each pilot phase.

Table 2. Data collection per country

Evaluation Tools	**Greek informal**	**Greek formal**	**Finnish informal**	**Finnish formal**
Students diaries	232	140	9	88

Teacher diaries	47	49	9	8
Student Final Questionnaires	41	37	20	56
Interviews with students	10*	6*	7	20*
Interviews with teachers	5*	4*	3*	7*
Observation forms	16	12	6	43
Narrative Reports	4			
Parents' statements	7			
* Including short interviews conducted in the context of festivals with students & teachers				

4 VALIDATION RESULTS

4.1. CREATIVITY VALIDATION

In this section, we present the detailed analysis of the findings on the validation of the creativity claim. The analysis of the collected data from various evaluation tools was used to investigate the validity of the claim that the eCraft2Learn intervention promotes creativity. The results of the analysis are in line with the validity of specific points that were identified during the literature review and that the eCraft2Learn interventions provide students with the opportunity to become creative and develop their creativity. Furthermore, the analysis examines if the project-based and crafting type of intervention fosters opportunities to deal with failure in the process, and produce difficult and high quality projects. In addition to that, if there was a community atmosphere, a secure and interactive environment to provide additional clues about the claim of creativity. Thinking strategies, debugging and computational problems that were investigated could further support the creativity claim as indicative examples that foster creativity.

4.1.1. RESULTS FROM STUDENT DIARIES

Significant insights towards validating the eCraft2Learn intervention with respect to student creativity were gained from student diaries. In particular, the answers to the first question of "*What did you like the most today?*" reveals cases that are worth mentioning, for instance: "*I liked that we finally managed to make the sunflower after a lot of trouble*", "*I liked that we made an interesting construction and made it very complicated*", "*I liked that we managed to make the sunflower after lot of effort*". Students were also pleased with the fact the they materialized some 3D printing constructions: "*I liked that we were manage to print 3D*"; robots with artificial intelligence: "*I liked the idea of making the robot move with voice commands*", "*That we made the program for Artificial Intelligence with Snap4Arduino humanoid*"; but also general constructions: "*The construction of the* *rabbit*”, “*The construction of the rabbit and the voice command…*”, “*it was fascinating when we were making noise over the threshold the rabbit was hiding.*”. In addition, achievements in programming were not insignificant either to students, referring to robot programming: “*Today I liked more that we managed to make our robot turn*”, “*Today I liked more the robot programming*” and “*Today what I liked the most was that I managed to turn on the led*”. They also enjoyed achievements related to things that they had never tried before: “*Today, I like it that I tried to program, because I have never done something like this in my life.*”, “*We combine our artefact with 3D printing*”. Furthermore, some students from the Finnish pilot site also referred to 3D printing: “*Making flower with 3D printer”, “A model of a palm tree that we made for 3D printing with a computer*”.

There were also other comments about various constructions, including: “*Building lighthouses*“, “*I like the remote controlled car*”, “*I liked a lot the construction*”, “*I liked that we made the bridge*”, “*I liked the fact that we made something related to Christmas*”. Students also enjoyed the coding: “*That we used programming to control the leds*”, and they were proud of their achievements: “*The functional final outcome*”, “*the hands on constructions!*”, *“...Also I liked how in the end we brought all the parts together.*”, “*We put the solar panel into operation with the photoresist*”.

They were also excited about craft and making, with at least 14 students mentioning these: “*Crafting is fun! Everything was fun. It was nice that we got our plan done.*”, “*Combining lights and crafts*”, “*I liked the most making the flower and when everyone were moulding the flower*”. Also during the second pilot round 9 students mentioned crafting: “*Building the project*” and “*Crafting*”.

The abovementioned can be interpreted as students’ acknowledgement and recognition that they have an open attitude to new ideas, the knowledge and skills to create these new ideas, as well as to work on the ideas, and that tackling failure in the process, confronting the difficulties they faced dealing with them efficiently is something they enjoyed.

On the other hand the answers to the question “*What did you like the least today?*” that are significant are those alluding to teaching methods. The most noteworthy comments are: “*A very theoretical part that made the lesson slow, in my opinion*”, “*Continuous repetition of recycling of ideas”, “Listening (too long speech)*”, “*When doing nothing but listening*” which are not only different from the target of the project but also reduce creative time for the students. In addition to this, some technical issues like the comment: “*That at the begin I did not understand what to do (connections, breadboard, Arduino etc.)*”, 9 students mentioning: “*Not knowing how the work will proceed.*”, “*Choosing the electronics (what we need)*”, “*If I didn't understand*”, and many more similar comment in all rounds of the pilot project, provide a strong indication at times students did not have enough knowledge or resources to be creative.

4.1.2. Results from Teacher Diaries

The answers to the quantitative question “*Create. Did the students go through this stage today?*” played an important role in evaluating the effect of the eCraft2Learn intervention on student creativity. The results, based on the numbers of table 6 (Appendix 10), illustrate that teachers on both site types, formal and informal, answered predominantly “*Yes*” (75,10%) to this question. A similar result was obtained from the sites of both countries (72,77%). Further analysis using the generalisation of Fisher exact test for IxJ tables, reveals a few interesting facts. There is a statistically significant correlation (p = 0,02) between the type of site and the responses of teachers to the question "*Did students pass the creation stage?*" as well a statistically significant correlation (p = 1,44e-10 < 0,05) between creativity at pilot sites in both countries. This might be due to the high percentage (57,59%) of "*Yes*" answers at the informal sites. In addition, an informal environment is said to be creative by nature of its openness, the relaxing atmosphere that students and tutors enjoy. In contrast, in a formal school class the mentality, routine, time limits and the atmosphere restrict the students. This, among other things, contributes to the general conclusion that the intervention was one of creativity for students, with more creativity being present at informal sites. As far as the comparison of pilots at two sites, we have already referred to literature that in Finland several development projects have been started, aimed at developing the curriculum and technology education (Järvinen, E.M. et. al. 2000; Lavonen, J. et. al. 2004; Parikka, M. et. al. 2009). The Finnish curriculum in 2004 emphasized the meaning of technology from the point of view of everyday life. Students are familiar with new technology, including ICT, how it is developed and what kind of influence it has. On the other hand, there is no such intervention in Greek public schools and students are not used to interventions like this. In addition, we found that there is a statistically significant correlation of pilot types in Greece regarding this question (p=0,002), which further supports our claim that although Greek students are capable of creativity, tutors maintain that within the formal school environment they are not so creative.

Teacher questionnaires include a question about project description. The variety of projects that students did, according to their teacher's description, illustrates that students were rather creative in the variety of projects that they aimed to construct. In both countries, and at both formal and informal pilot sites, teams materialised project ideas such: as a security alarm system with three zones using a distance sensor and LED lights for the alarm notification, a control system with photoelectric sensors, a robot with a distance sensor, a robot that follows light, an autonomous robot using Raspberry Pi and without Arduino, a car with a distance detector, a fully functional bridge at a Greek formal pilot site, and combining electronics and 3D printing. Some students from the informal site in Finland had ideas such as: high five robot, interactive art, motion detector projects as a head and a lighting system in a house, robot head, and smart homes. This is quite a large variety of new ideas and approaches to creative projects that students came up with. All projects are of high quality, evaluated by tools, promote creativity, and include computational problems and debugging.

4.1.3. Results from Observation Forms

The results from the observation form evaluation tool are of importance for the question of creation during the pilot materialisation phase. Among other questions, the observer has to respond to the creation related closed questions and comment field. This question offers data on the evaluation of the creation of new ideas, which is a key point in the evaluation of creativity. Table 15 in Appendix 1 shows the number of "*Yes*", "*Yes, but to a limited extent*", and "*No*" answers to each of the questions about creation for each pilot site separately. The analysis reveals various interesting findings. The "*Yes*" response appeared in 71,38% of answers in total, at both formal and informal sites. In addition, there is a statistically significant correlation (p=0,01) between the pilot site type and the answer of creativity. The explanation is the same as in the case of teacher diaries results for creativity. Regarding the comparison between the two countries, there is a statistically significant correlation (p=0,006) between country and the creativity that observers noticed in various sessions. Hence, there is one more piece of evidence based on the results of this question - that creativity is related to pilot site type and country of intervention.

4.1.4. Results from Interviews with Teachers

Some teachers pointed out that students had limited learning on the subject matter itself during the eCraft2Learn project but, unlike in other school work, students improved their programming and technological skills as well as creative thinking. Therefore, the knowledge gain developed during the eCraft2Learn project is much different from normal lessons and instead teaches students skills that they can use and apply later, as opposed to focusing on small details of the subject matter.

> *"There was plenty of time for own ideation and crafting. In the normal school work there is not so much time, possibilities, for it. But students enjoy it. In that sense it was great that there was something else. -- Making in some way motivates much more than only theory itself. " (Teacher B FIN)*

Another issue that was raised by the teachers is related to the initial support that should be provided in order to familiarize the students with the underpinning procedures and the eCraft2Learn tools and technologies. Once, this level of support has been provided, the students can build on this, working more confidently on their own ideas, extending their projects and creatively providing solutions to the emerging problems (see also D5.5).

> *"In the beginning they [the students] were a bit disorganised and they had difficulties on starting working on the projects but slowly they got familiar with the whole procedure and tools and they started taking the initiative in working on their own ideas". (Participating teacher, GR)*

4.1.5. Results from Final Student Questionnaires

The answers to the quantitative question "*During the workshop I was able to be innovative?*" reveals important outcomes for the creativity pedagogical aspect. Innovation is closely related to creativity and according to Binkley (Binkley, M. et. al. 2012, p.38), creativity and innovation can logically be grouped together. The cumulative data in Tables 16 and 17 (Appendix 1) illustrates that teachers on both formal and informal sites, answered predominantly "*Yes*" (66,23%). The result is the same in both countries (66,23%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p = 0,02) between the type of site and the perception of teachers to the question "*During the workshop I was able to be innovative?*" as well a statistically significant correlation (p=4,286e-006 < 0,05) at pilot sites between the two country sites and the responses of students to the same question. We noticed that innovation follows the same pattern as the question of creation in teacher diaries. According to the literature, measuring both can be quite challenging. The tasks require an interactive environment (Binkley, M. et. al. 2012, p.38).

The analysis of data for the quantitative question "*During the workshop I was able to be creative*", which is a direct reference to creativity, shows (Tables 21 and 22 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly "*Yes*" (77,92% - 77,92%). But in this case there is no statistically significant correlation in either case, neither for pilot site types (p=0,53) nor for countries (p=0,32) according to the Fisher exact test. We noticed that here creation related questions did not follow the same pattern as questions about innovation and as question of creation in teacher diaries. This can be explained by the difference in the number of "*Yes*" answers between innovation and creation per country (Tables 19 and 21) and per pilot type (Tables 20 and 21).

The analysis of data for the quantitative question "*During the workshop I was able to do the things the way I preferred*", is another way to evaluate the potential for new ideas and the level of environment security. The data (Tables 25 and 26 - Appendix 1) shows that teachers at both formal and informal pilot sites, and in both countries, answered predominantly "*Yes*" (60,39% - 60,39%). But in this case there is no statistically significant correlation in either cases, neither for pilot site types (p=0,16), nor for countries (p=0,32) according to the Fisher exact test, which can be explained by the fact that the eCraft2Learn environment provides an environment of openness that helps foster every new idea.

The analysis of data for the quantitative question "*I feel more comfortable than before I programmed*", (Tables 29 and 30 - Appendix 1) shows that students at both formal and informal pilot site, and in both countries, answered predominantly "*Yes*" (56,49% - 56,49%). In this case there is a statistically significant correlation between countries and whether students feel more comfortable than before programming (p=9,192e-005 < 0,05). On the other hand, there is no statistically significant correlation between site types and whether students feel more comfortable than before programming (p=0,25) according to the Fisher exact test. This is due to 71,79% of Greek pilot students feeling more comfortable after the intervention compared with 40,79% of the Finnish students. This can be explained by the fact that Finnish students had already taken part in similar programs since STEM is integrated into the formal school curriculum, whereas Greek students did not have such opportunities prior to the intervention.

The analysis of data for the quantitative question "*I feel more comfortable than before to make and craft things*", (Tables 31 and 32 - Appendix 1) shows that teachers at both formal and informal pilot site, and in both countries, answered predominantly "*Yes*" (59,09% - 59,09%). But in this case there is no statistically significant correlation in either cases, neither for pilot site types (p=0,015), nor for countries (p=0,018), according to the Fisher exact test. This indicates that the intervention offers real craft projects which are not dependent on the pilot site.

The analysis of data for the quantitative question "*I feel more comfortable than before to work with electronics*" presented below. The results show (Tables 33 and 34 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly "*Yes*" (62,99% -

62,99%). In this case there is a statistically significant correlation in both cases, for pilot site types (p=0,001) and countries (p=0,0013) according to the Fisher exact test. The result indicates that previous knowledge or experiences accounts for the difference between the two countries as well as that students at informal pilot sites had more prior experience in comparison to students at formal sites that do not have many of opportunities to work on electronic projects.

The contribution of the question "*Any other thing that you feel more comfortable to do than before? If so, which:*" to the validation of creativity include statements such as: “*Finding more ideas*” (1st session) and “*Find new ideas for the project*” (2nd session), which are indicative of the creativity of students. It was found that students felt comfortable with finding ideas in both sessions.

The response to the question “*During the workshop I liked most*”, the students at Finnish pilot sites reported that they most enjoyed completing their projects, planning and collaborating, crafting and programming primarily. Also, the students were excited about working within the eCraft2Learn learning ecosystem to achieve their goals. At Greek pilot sites, students reported that during the 1st pilot session: “*I liked the fact that the realization of each project was done with simple daily materials and the pleasant atmosphere that prevailed as we were all guided, helped and inspired by the other teams….*”, and that “*I liked that …… we could all deal with the difficulties we eventually had to face…*”. Finally and most noteworthy, students mentioned “*the creativity*” (two students), “*The concept*” and programming. These comments reveal the creative side of the sessions as well as the skills that students gain through the intervention.

4.1.6. Creativity Validation: Conclusions

In this subsection, we summarise the findings that are related to the aspect of creativity. To begin with, it seems that the eCraft2Learn ecosystem encouraged learners to generate ideas and to develop their skills in order to extend and to enrich these ideas. The eCraft2Learn pedagogical framework gave students the opportunity to act creatively and find solutions in the area of programming and beyond, while at the same time practicing and further developing their interpersonal skills. The students were seen to deal creatively with the failures and the difficulties that were emerging. The conditions for fostering creativity were present: an open environment that embraces failure and welcomes meaningful interactions towards creative computer-supported artefacts constructions. However, this creative tendency at the formal pilot sites was hindered by time constraints related to school program and formal school organizational procedures. It is worth mentioning that the students at the informal pilot sites seem to highlight more the creative nature of the eCraft2Learn environment. The evaluation tools that were found useful to elicit feedback related to the aspect of creativity are: student diaries, teacher diaries, interviews with teachers, final student questionnaires and observation forms.

4.2. Critical Thinking Validation

In this section we present the detailed analysis of the findings on the validation of the critical thinking claim. The analysis of the collected data from various evaluation tools were used to investigate the validity of the claim that an eCraft2Learn intervention promotes critical thinking. The results of the analysis confirm the validity on specific points that were identified during the literature review and that the eCraft2Learn intervention provide students the opportunity to be involved in thinking and decision making, in the same way as throughout the different stages of programming (Gary Ka-Wai Wong, et al. 2018). Students passed through the intellectually disciplined process of actively and skilfully conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. We analysed the evaluation of actions taking place during the intervention, which brought forth critical thinking, knowledge, skills and attitudes and others where students had to make reasoned judgements and decisions, and articulate these through clear explanation and justification of the process in order to reach the construction. Through the activities, students had to think critically, which helped them to resolve ambiguity and embrace or adapt to continuous social, cultural and technological change. In addition to this, they had to manage a considerable amount of information, presenting intellectual curiosity and rigor to the new as well as creativity, imagination and ethical values such as integrity and tolerance to reach their goals. Finally, we analysed the evaluation data concerning the broad range of ICT tools and programming opportunities offered within the eCraft2Learn intervention. According to Lye (Lye, S. Y. et. al. 2014) and Wright (Wright, G. A. et. al. 2012) part of programming through CT is critical thinking since children participate in the programming process. In addition, children solving any kind of computational problem requires constant judgement and justification of the process, from algorithm design to testing and debugging.

4.2.1. Results from student diaries

Although most of the students commented that they liked everything and a significant number that they gained knowledge to the question *"What did you like the most today?"* there are some other comments related to critical thinking that was fostered during the intervention. In particular, students mentioned some of their achievements referring to issue related to the critical thinking claim, such as: *"I liked that we finally managed to make ……. after a lot of trouble", "I liked that we made an interesting construction and made it very complicated",* and *"I liked that we managed to make the sunflower after lot of effort"*, which means that they recognized and confronted the difficulties they faced, employing critical thinking to solve the problems.

4.2.2. Results from Teacher Diaries

The answers to the quantitative question *"Ideation/Imagine. Did the students go through this stage today?"* reveal important outcomes. The cumulative data in Table 4 (Appendix 1) shows that teachers predominantly answered *"Yes"* (81,42%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,001) between the pilot site and the perception of teachers whether students go through the stage of Ideation/Imagine during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (1) and informal Finnish (3) pilot sites, where students partly completed this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (12) and formal Finnish (16) pilot sites, where not all students went through this stage. We have to mention that the Ideation/Imagine phase was not included in all sessions of second round open projects. Ideation/Imagine is a very important step in the process of critical thinking that includes decision-making, applying, analysing, synthesizing and this finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question *"Planning. Did the students go through this stage today?"* reveals important outcomes. The cumulative data in Table 5 (Appendix 1) illustrates that teachers predominantly answered *"Yes"* (81,42%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,001) between the site and the perception of teachers whether students went through the stage of Planning during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (1) and informal Finnish (3) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes but to a limited extent"* answers from informal Greek (18) and formal Finnish (19) pilot sites, where in a number cases students did not go through this stage. We have to mention that the Planning phase was not included in all sessions of second round open projects. Planning is a very important step in the process of critical thinking that includes decision-making, applying, analysing, synthesizing and this step proved to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question *"Program. Did the students go through this stage today?"* reveals important outcomes. The cumulative data in Table 7 (Appendix 1) illustrates that teachers predominantly answered *"Yes"* (81,42%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=6,224e-011 < 0,05) between the site and the perception of teachers whether students went through the stage of Program during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from the informal Finnish (2) pilot site, where students mostly did not go through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (20), formal Greek (12) and formal Finnish (13) pilot sites, where a number students did not go through this stage. We have to mention that the Program phase was not included in all sessions of second round open projects. Program is a very important step in the process of critical thinking that includes decision-making, applying, analysing, synthesizing and this finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

4.2.3. Results from Observation Forms

The answers to the quantitative question for the Ideation stage reveal important outcomes. The cumulative data in Table 13 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at every pilot site (54,29%, 91,67%, 60,61%, 57,86%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=6,187e-006 < 0,05) between the pilot site and the perception of observers that students went through the stage of Ideation during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (5) and informal Finnish (11) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes but to a limited extent"* answers from informal Greek (19) and formal Finnish (45) pilot sites, where a number of students did not go through this stage. We have to mention that the Ideation phase was not included in all sessions of second round open projects. Ideation is a very important step in the process of critical thinking that includes decision-making, applying, analysing, synthesizing and this finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question for the Planning stage reveals important outcomes. The cumulative data in Table 14 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at every pilot site (48,61%, 88,14%, 66,67%, 49,37%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=2,648e-011 < 0,05) between the pilot site and the perception of observers that students went through the stage of Planning during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (7) and informal Finnish (11) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (25) and formal Finnish (31) pilot sites, where a number of students did not go through this stage. We have to mention that the Planning phase was not included in all sessions of second round open projects. Planning is a very important step in the process of critical thinking that includes decision-making, applying, analysing, synthesizing and this step proved to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question for the Program stage reveals important outcomes. The cumulative data in Table 16 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at every pilot site (80,56%, 46,67%, 60,61%, 56,96%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=8,717e-008 < 0,05) between the pilot site and the perception of observers that students went through the Program stage during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from informal Greek (5) and informal Finnish (2) pilot sites, where students mostly went through this stage. On the other hand, there is a rather higher percentage of *"Yes, but to a limited extent"* answers from formal Greek (18) and formal Finnish (8) pilot sites, where a number of students did not go through this stage. We have to mention that the Program phase was not included in all sessions of second round open projects. The Program stage is a very important step in the process of critical thinking that includes decision-making, applying, analysing, synthesizing and this finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

4.2.4. Results from Final Student Questionnaires

The analysis of data for the quantitative question *"During the workshop I was able to do the things the way I preferred."* shows (Tables 25 and 26 - Appendix 1) that teachers at both formal and informal pilot site s, and in both countries, answered predominantly *"Yes"* (60,39% - 60,39%). But in this case there is no statistically significant correlation in either case, neither for pilot site types (p=0,16), not for countries (p=0,32) according to the Fisher exact test. This can be explained by the fact that the eCraft2Learn environment provides an open environment that fosters freedom in decision-making.

The analysis of data for the quantitative question *"During the workshop I was able to test and try out"* shows (Tables 23 and 24 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (60,39% - 60,39%). But in this case there is no statistically significant correlation in either case, neither for pilot site types (p=0,16), nor for countries (p=0,32) according to the Fisher exact test. This proves that the eCraft2Learn intervention provides the students opportunities irrespective of the pilot site, in particular to be actively involved in thinking and decision-making, analysing, synthesizing and algorithm design, testing and debugging.

The analysis of data for the quantitative question *"I feel more comfortable than before I programmed"* shows (Tables 29 and 30 - Appendix 1) that students at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (56,49% - 56,49%). In this case there is a statistically significant correlation between countries and whether students feel more comfortable than before programming (p=9,192e-005 < 0,05). On the other hand, there is no statistically significant correlation between site types and whether students feel more comfortable than before programming (p=0,25) according to the Fisher exact test. This might be due to 71,79% of Greek pilot students feeling more comfortable after the intervention compared to 40,79% of Finnish students. This can be explained by the fact that Finnish students had already taken part in similar programs since STEM is integrated into the formal school curriculum, whereas Greek students did not have such opportunities prior to the intervention.

The analysis of data for the quantitative question *"I feel more comfortable than before working with electronics"* shows (Tables 33 and 34 - Appendix 1) that teachers at both formal and informal sites, and in both countries, answered predominantly *"Yes"* (62,99% - 62,99%). In this case there is a statistically significant correlation in both cases, for pilot site types (p=0,001) and countries (p=0,001) according to the Fisher exact test. This can be explained by the fact that Finnish students had already taken part in similar programs since STEM is integrated into the formal school curriculum, whereas Greek students did not have such opportunities prior to the intervention.

4.2.5. Critical Thinking Validation: Conclusions

In this subsection, we summarise the findings that are related to the aspect of critical thinking. To begin with, it seems that the participating students recognized and confronted the difficulties they faced, employing critical thinking while solving problems during their projects. In addition to this, they made decisions during the Ideation/Imagine stage, which has a statistically significant relation to the pilot site. This means that each pilot site has a different perception of the Ideation\Imagine stage application, possibly due to the different experience, knowledge and way of working at each pilot site. Furthermore, evidence from the planning stage supports the claim of critical thinking since students passed through the intellectually disciplined process of actively and skilfully conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered. Students had the opportunity to test and try out, which proved independent of the pilot site, meaning that the eCraft2Learn intervention provide students the opportunity to be actively involved in thinking and decision making, analysing, synthesizing and algorithm design, testing and debugging, irrespective of the pilot site. Teachers stated that during the pilots students went through Programming successfully, a stage which includes critical thinking, an essential part of the computational thinking. Students feel more comfortable programming after the pilots, which has a statistically significant correlation between countries. This might be due to 71,79% of Greek pilot students feeling more comfortable after the intervention compared to 40,79% of Finnish students. This can be explained by the fact that Finnish students had already taken part in similar programs since STEM is integrated into the formal school curriculum, whereas Greek students did not have such opportunities prior to the intervention. The evaluation tools that supported the validation of critical thinking claim are: student diaries, teacher diaries, observation forms, and final student questionnaires.

4.3. Problem-solving Validation

In this section we present the detailed analysis of the findings regarding the validation of the problem solving claim. The analysis of the collected data from various evaluation tools were used to investigate the validity of the claim that an eCraft2Learn intervention promotes problem solving. The results of the analysis confirm the validity on specific points that were identified during the literature review and that the eCraft2Learb intervention provide students the opportunity to be involved in pragmatics, the way that context contributes to meaning, and semantics, the interpretation of the problem. Students used abstract thinking or came up with a creative solution (Schacter, D.L. et. al. 2009). During the intervention students used problem-solving strategies such as taking steps to confront the problems. During the analysis we tried to investigate references to well-known problem-solving methods, such as abstraction, analogy, brainstorming, hypothesis testing, trial-and-error, all evaluated by our tools. The eCraft2Learn educational cycle is examined with respect to the idea that literature describe the problem solving cycle, composed of steps of problem recognition, as problem definition, developing a strategy to solve the problem, organising the knowledge of the problem, identifying the resources at the user's disposal, monitoring one's progress, and evaluating the solution for accuracy. Within the evaluation of the eCraft2Learn pedagogical framework we examined whether during pilots students used techniques of algorithms, computerized processes, using computer-based learning environment for collaboration to stimulate student learning and the process of inquiry (Wasson, B. et al. 2003; Laurillard, D. 2009). The eCraft2Learn digital tools evaluated whether they can support collaboration in problem solving, creative practices, and communication by means of evaluation tools.

4.3.1. RESULTS FROM STUDENT DIARIES

The replies to the question *"What did you like the most today?"* related to the issue of problem solving on a variety of points. In particular, the comment made by the students *"That I can build an autonomous artefact"* illustrates the ability to solve a problem concerning the construction of a specific artefact. Other points on achievements that students made are indicative of problem solving capabilities. Students' statements, including *"I liked that we finally managed to make the sunflower after a lot of trouble", "I liked that we made an interesting construction and made it very complicated"* and *"I liked that we managed to make the sunflower after lot of effort"* are indicative of students recognizing the difficulties they faced and that they ultimately dealt with them efficiently and in a methodological manner. At the Greek formal site, the comments relating to problem solving that we received were mainly about solutions towards reaching the final objectives. Indicative comments include *"The functional final outcome", "the hands on constructions!", "...Also I liked how in the end we brought all the parts together."* and *"We put the solar panel into operation with the photoresist".* Similar references were received from Finnish sites, with the most noteworthy being: *"Crafting is fun! Everything was fun. It was nice that we got our plan done."* and *"I liked the most today when we managed to finish our work and the result is excellent and unique in our opinion."*

Furthermore, the most important aspect of programming according to the literature, was frequently mentioned by many students: *"Today I liked more that we managed to make our robot turn", "Today I liked more the robot programming"* and *"Today what I liked the most was that I managed to turn on the led"*. More specific references to programming were also made: *"App Inventor"*, with many students referring to this, *"Arduino programming"* and *"How we programmed with Snap4Arduino"*, which were mentioned by quite a few students, *"I enjoyed setting up the commands that made the led flash.",* and more generally the phrase *"The programming"*. They also enjoyed problem solving related to aspects that they had never tried before: *"Today, I like it that I tried to program, because I have never done something like this in my life."* and *"We combine our artefact with 3D printing".* It would seem that the eCraft2Learn intervention was in accordance with what we found in the literature - which programming is a serious process and that in fact, the CT process is triggered if and only if there is a computational problem to be solved. Through a series of thinking processes and skills, the ultimate goal is to solve the programming problem by developing a computer program as a digital artefact (Ka-Wai Wong, et al., 2018).

According to the literature, children can learn how to solve problems by themselves, and collaborative problem solving can also occur during the coding process (Israel, M. et. al. 2015). The question *"What did you like the most today?"* in student diaries produced a significant number of responses on this subject. A considerable number of positive comments were made regarding collaboration: *"Collaboration and teamwork", "team discussion about all team project and their idea", "I liked it that we worked well all together and we made something as a team"* and "*The collaboration to find nice ideas",* as well as about the method used: *"I liked it today when we planned and made everything we needed today"* and *"I liked that we all worked together and we had a great result"*. It is worth noticing that although all these comments made by students initially appear to be about collaboration, there are aspects that directly refer to problem solving, results, methodology of problems solutions, and so on. There are some very interesting comments about the way teachers worked with students that have critical references to problem solving issues: *"I liked that we were left by our teacher to explore ourselves the solutions of some problems that emerged."* and *"I really enjoyed the collaboration we had with my team and teachers..."*. The whole environment seemed to have played a positive role since there are comments such as: *"The nice atmosphere within the team".* Apart from this, from Finnish site we have comments like *"When after a hard work we managed to turn on the lights and got our plan made"*. These comments strongly support that the collaborative environment that the eCraft2Learn ecosystem reinforce, foster a problem solving mentality.

4.3.2. Results from Teacher Diaries

The answers to the quantitative question *"Ideation/Imagine. Did the students go through this stage today?"* reveal important outcomes. The cumulative data in Table 4 (Appendix 1) illustrates that teachers predominantly answered *"Yes"* (81,42%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,001) between the site and the perception of teachers whether students went through the stage of Ideation/Imagine during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (1) and informal Finnish (3) pilot sites, where students mainly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (12) and formal Finnish (16) pilot sites, where a number of students did not go through this stage. We have to mention that the Ideation phase was not included in all sessions of second round open projects. Ideation and Imagine is a very important step in the process of problem solving and includes problem recognition, problem definition, developing a strategy to solve the problem, organising the knowledge of the problem, identifying the resources at the user's disposal, monitoring one's progress, and evaluating the solution for accuracy - a step that proved to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question *"Planning. Did the students go through this stage today?"* reveal important outcomes. The cumulative data in Table 5 (Appendix 1) illustrates that teachers predominantly answered *"Yes"* (81,42%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,001) between the site and the perception of teachers whether students went through the stage of Planning during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (1) and informal Finnish (3) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (18) and formal Finnish (19) pilot sites, where a number of students did not go through this stage. We have to mention that the Planning phase was not included in all sessions of second round open projects. Planning is a very important step in the process of problem solving and includes problem recognition, problem definition, developing a strategy to solve the problem, organising the knowledge of the problem, identifying the resources at the user's disposal, monitoring one's progress, and evaluating the solution for accuracy - a step that proved to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question *"Program. Did the students go through this stage today?"* reveal important outcomes. The cumulative data Table 7 (Appendix 1) illustrates that teachers predominantly answered *"Yes"* (81,42%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,001) between the site and the perception of teachers whether students go through the Program stage during the intervention. This statistically significant difference might be due to the very small number of answers *"Yes, but to a limited extent"* from the informal Finnish (2) pilot site, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (20), formal Greek (12) and formal Finnish (13) pilot sites, where a number of students did not go through this stage. We have to mention that the Program phase was not included in all sessions of second round open projects. Program is a very important step in the process of problem solving that includes decision-making, applying, analysing, synthesizing and this finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

Teacher diaries include a question about project description supporting the creativity of the teams. But any creative project and any construction face difficulties. Student groups managed to produce such a wide range of projects, forging their own path towards their final achievements. Firstly, this statement can be illustrated with reference to the projects during the 1st round at both sites. At the Greek informal pilot site teams chose the Lighthouse project, the Shy Rabbit project, the Sunflower project, the Christmas artefacts (Christmas trees, Christmas boxes with music, Christmas figures and more) and DIY automobiles (simple to more complex implementations); while at the Greek formal site in the 1st round teams worked on the Lighthouse project, the Small village (as an extension of the Lighthouse project), the Christmas artefacts, the Sunflower project, the Solar panel (based on functionalities of the Sunflower project) and DIY automobiles (simple ones). As for the Finnish pilot sites in the first round, teams at the informal pilot site undertook the Robot head project and at the formal site they chose Photosynthesis project 1, Security in society and Photosynthesis project 2. In deliverable D5.5 (Small case pilot report and videos of good practices), there are pictures and videos that provide compelling evidence, that although during the 1st pilot round groups had to do more or less the same context projects, they constructed artefacts unique to each group.

During the second pilot round the idea was to have a more free selection and open projects. At the Greek informal pilot site groups developed project ideas like The 3 level security control system, Joypad for controlling a video game, Voice driven face project (AI) and Advanced DIY automobiles with remote control. At the Greek formal pilot site the Advanced DIY automobiles project was undertaken. At the Finnish informal pilot site students came up with the ideas of Smart Home and Interactive Art projects. Students at the Finnish formal pilot site materialised the Cold War, the Geographical Phenomena and the Solar System projects. All the above mentioned projects, together with the unique characteristics of each team's project, reveal that each student team encountered different problems and solved them in a unique way to achieve the final artefact, either by utilising team members' personal qualities and ideas, collaboration ideas or even cross team collaboration. The detailed descriptions of the projects and indicative pictures can be found in deliverable D5.5 (Small case pilot report and videos of good practices).

As far as the question *"Did you learn something new from your interaction with the students today?"*, teachers referred to aspects of problem solving in two ways. The first is about the way of teaching that promotes problem solving abilities for students as well as collaborative issues. In particular, they noted that children preferred a more practical teaching approach, with greater freedom to experiment and to try to rely on their own abilities and capabilities with comments like *"Children are more keen in trying from the moment they realize that there might be more than one solution to a problem.",* and *"They managed to complete the previous project, believing in themselves, even though all the other teams were moving faster ….".* Furthermore, we have to mention the comment of a teacher that saw new sides of the students and felt that the experiences students get from eCraft2Learn projects provide invaluable feedback for some students that they actually can succeed, resulting in feelings of accomplishment and achievement. These notes illustrate that children have the inherent tendency of human beings to use a problem solving approach to overcome any problem they may encounter.

Furthermore, there were some interesting diary entries about collaboration like these ones about team self-regulation and its contribution to problem solving: *"Disagreement sometimes can be creative. A combination of ideas could be chosen, but next day, unfortunately there was a change in the members of the team."* and *"Creativity gives results. And harmonic cooperation"*. Most noteworthy is the comment that effective team collaboration does not necessarily take time, *"Children can easily cooperate together on a project even if they briefly known each other".*

4.3.3. Results from Observation Forms

The answers to the quantitative question for the Ideation stage reveal important outcomes. The cumulative data appeared in Table 13 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at every pilot site (54,29%, 91,67%, 60,61%, 57,86%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation ($p=6{,}187e\text{-}006 < 0{,}05$) between the pilot site and the perception of observers that students went through the stage of Ideation during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (5) and informal Finnish (11) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (19) and formal Finnish (45) pilot sites, where a number of students did not go through this stage. We have to mention that the Ideation phase was not included in all sessions of second round open projects. Ideation is a very important step in the process of problem solving that includes that includes problem recognition, problem definition, developing a strategy to solve the problem, organising the knowledge of the problem, identifying the resources at the user's disposal, monitoring one's progress, and evaluating the solution for accuracy - this step proved to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question for the Planning stage reveal important outcomes. The cumulative data in Table 14 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at every pilot site (48,61%, 88,14%, 66,67%, 49,37%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation ($p=2{,}648e{-}011 < 0{,}05$) between the pilot site and the perception of observers that students went through the stage of Planning during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (1) and informal Finnish (3) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (18) and formal Finnish (19) pilot sites, where a number of students did not go through this stage. We have to mention that the Planning phase was not included in all sessions of second round open projects. Planning is a very important step in the process of problem solving that includes problem recognition, problem definition, developing a strategy to solve the problem, organising the knowledge of the problem, identifying the resources at the user's disposal, monitoring one's progress, and evaluating the solution for accuracy - this step proved to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question for the Program stage reveal important outcomes. The cumulative data in Table 16 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at every pilot site (80,56%, 46,67%, 60,61%, 56,96%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation ($p=8{,}717e{-}008 < 0{,}05$) between the pilot site and the perception of observers that students went through the Program stage during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from the informal Finnish (2) pilot site, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (20), formal Greek (12) and formal Finnish (13) pilot sites, where a number of students did not go through this stage. We have to mention that the Program phase was not included in all sessions of second round open projects. Program is a very important step in the process of problem solving that includes decision-making, applying, analysing, and synthesizing - this finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question for Project/Artefact construction reveal important outcomes. The cumulative data in Table 18 (Appendix 1) illustrates that observers predominantly answered *"Yes"* at three of the pilot sites (57,33%, 84,85%, 79,75%). Further analysis using the generalisation of Fisher exact test reveals a few interesting facts. There is a statistically significant correlation ($p=2{,}841e{-}019 < 0{,}05$) between the pilot site and the perception of observers that students accomplished Project/Artefact construction. This might be due to students at the formal pilot sites not having the time to accomplish the projects in one session.

4.3.4. Results from Interviews with Teachers

The eCraft2Learn pilots included more long-term project work compared to normal school work. These projects helped students to **develop skills in planning and testing** as well as in **recovering after a failure and finding ways to cope with the challenges and difficulties**.

> *"...the understanding of doing things by themselves, building things, collaborating, learning through experience, make mistakes all those things are vital for their own mentality, for the future of their education and those things are difficult to learn, so through all those sessions and workshops the students I think realized how important it is for them to collaborate, go deeper, explore new tools and techniques, new approaches, in this experiential learning procedure." (Teacher A, GR)*

In close connection to problem solving, other different skills are a precondition. Given that the pilots were designed to **allow for a larger degree of openness and also for steering their own learning, it consequently fostered students' self-regulation and metacognitive skills.** Failing should not be considered as 'not learning' but instead one way to solve a problem; by understanding what does not work, students come closer to the understanding of what could work.

> *"How do you get over it and start planning again in case you fail." (Teacher E, FIN) and "School work should have more of these longer-lasting projects to help students to learn planning skills and strategies to cope with the failure." (Teacher D, FIN)*

Still, it has to be mentioned that not all students adjust to open learning by solving problems as fast as others. Most students are used to being provided with ready answers to solving a problem, and consequently displayed greater difficulties than expected when confronted with the eCraft2Learn learning environment. It is recommended to take into consideration that this type of learning needs some time to adjust to, not only students, but also teachers (acting as facilitators).

> *"When we think about problem solving in programming, one member from each team had the biggest responsibility for it, at least it was the case in the boys-only team. But in girl-only teams I think all girls improved their skills in programming. Of course problem solving was necessary in many other parts of the work so maybe those [who did not program] solved problems in some other phase." (Teachers E FIN).*

4.3.5. Results from Interviews with Students

In line with teacher interviews, some students seemed to be content with being challenged to find their own solutions (*"I prefer this kind of a learning over the traditional one."* (Group D, Students A and B), while other students commented that the fact that they had to solve problems was rather 'un*comfortable*' for them. This is again in line with the observations of the coaches who mentioned that students need time to adjust to this teaching/learning method.

Still, many students mentioned also an **increased competence in solving problems and collaboration**: *"For me it was definitely a ground breaking experience, enjoyable and I really liked the fact that it was* *a workshop about STEM in which skills like solving problems and collaboration were developed [...]" Participant student (student from formal pilot site, Athens, GR).*

4.3.6. Results from Final Student Questionnaires

The analysis of data for the quantitative question *"During the workshop I was able to test and try out."* shows (Tables 23 and 24 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (60,39% - 60,39%). But in this case there is no statistically significant correlation in either cases, neither for pilot site types (p=0,16), nor for countries (p=0,32) according to the Fisher exact test. This proves that the eCraft2Learn intervention offers students the opportunity, irrespective of the pilot site, to be actively involved in problem recognition, problem definition, developing a strategy to solve the problem, organising the knowledge of the problem, identifying the resources at the user's disposal, monitoring one's progress, and evaluating the solution for accuracy.

The analysis of data for the quantitative question *"During the workshop I was able to do the things the way I preferred."* shows (Tables 25 and 26 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (60,39% - 60,39%). But in this case there is no statistically significant correlation in either cases, neither for pilot site types (p=0,16), nor for countries (p=0,32) according to the Fisher exact test. This can be explained by the eCraft2Learn environment providing an open environment that fosters problem recognition, problem definition, development of a strategy to solve the problem, organisation of the knowledge of the problem, identification of the resources at the user's disposal, monitoring of one's progress, and evaluation of the solution for accuracy.

The analysis of data for the quantitative question *"I feel more comfortable than before I programmed."* shows (Tables 29 and 30 - Appendix 1) that students at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (56,49% - 56,49%). In this case there is a statistically significant correlation between countries and whether students felt more comfortable than before programming (p=9,192e-005 < 0,05). On the other hand, there is no statistically significant correlation between site types and whether students feel more comfortable than before programming (p=0,25) according to the Fisher exact test. This is due to 71,79% of Greek pilot students feeling more comfortable after the intervention compared to 40,79% of Finnish students. This can be explained by the fact that Finnish students had already taken part in similar programs since STEM is integrated into the formal school curriculum, whereas Greek students did not have such opportunities prior to the intervention.

The analysis of data for the quantitative question *"I feel more comfortable than before making and crafting things."* shows (Tables 31 and 32 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (59,09% - 59,09%). But in this case there is no statistically significant correlation in either case, neither for pilot site types (p=0,015), nor for countries (p=0,018) according to the Fisher exact test. This shows that the intervention offers real craft projects which are not dependent on the pilot site.

The analysis of data for the quantitative question *"I feel more comfortable than before working with electronics."* shows (Tables 33 and 34 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (62,99% - 62,99%). In this case there is a statistically significant correlation in both cases, for pilot site types (p=0,001) and countries (p=0,0013) according to the Fisher exact test. This result indicate that previous knowledge or experiences account for the difference between the two countries, as well as the fact that students at informal pilot sites have more previous experience compared to students at formal sites who do not have a lot of opportunities to work on electronics projects.

The analysis of data for the quantitative question *"I feel more comfortable than before I tackled problems."* shows (Tables 35 and 36 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (51,95% - 51,95%). In this case there is a statistically significant correlation in both cases, for pilot site types (p=0,0003) and countries (p=1,64e-005 < 0,05) according to the Fisher exact test. This can be explained by the eCraft2Learn environment providing an open environment that fosters problem recognition, problem definition, development of a strategy to solve the problem, organisation of the knowledge of the problem, identification of the resources at the user's disposal, monitoring of one's progress, and evaluation of the solution for accuracy, though with interference from the site's culture.

The analysis of data for the quantitative question *"I feel more comfortable than before finding solutions to issues that we faced."* shows (Tables 37 and 38 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (57,79% - 57,79%). In this case there is a statistically significant correlation in both cases, for pilot site types (p=0,049) and countries (p=4,093e-005 < 0,05) according to the Fisher exact test. This can be explained by the eCraft2Learn environment providing an open environment that fosters problem recognition, problem definition, development of a strategy to solve the problem, organisation of the knowledge of the problem, identification of the resources at the user's disposal, monitoring of one's progress, and evaluation of the solution for accuracy, though with interference from the site's culture.

4.3.7. Problem-solving Validation: Conclusions

In this subsection, we summarise the findings that are related to the aspect of problem solving. Following the eCraft2Learn initiative, the students (having the teachers by their side) were seen to engage in problem solving and creative procedures while working towards their computer-supported artefact creation. The students worked actively and with great motivation on the projects by distributing roles and using each team members' strengths when working collaboratively towards the same visions and ambitious goals. Based on the comments raised by the students, problem solving was significantly boosted by collaboration practices in the eCraft2Learn workshops.

The iterative nature of the eCraft2Learn learning methodology allowed for reflection and helped students to see that failure is an important part of the problem solving, and the learning process in general. The analysis of the failure and continuous improvement process was important for the development of a growth mind-set and to encourage persistence, challenge seeking and learning. The teachers supported the generation of ideas to help overcome failures and to solve problems through the timely use of prompt questions, as well as by providing useful explanations and boosting students' self-confidence and 'can-do' attitude.

The evaluation tools that were exploited for the validation of the problem solving claim are: student diaries, teacher diaries, observation forms, interviews with teachers, interviews with students, final student questionnaires.

4.4. Collaboration Skills Validation

In this section we present the detailed analysis of the findings regarding the validation of the claim related to collaboration skills. The analysis of the collected data from various evaluation tools were used to investigate the validity of the claim that an eCraft2Learn intervention promotes teamwork skills. The results of the analysis confirm the validity on specific points that were identified during the literature review and that the eCraft2Learn intervention provide students the opportunity to be involved in collaborative activities in teams in ways simulating real life situations. We investigated whether students had the opportunity to interact effectively with others and in diverse teams in order to manage projects, as well to guide and lead others or be responsible to others. Additionally, we investigated the extent to which students had the opportunity to engage in interactive reflective activities such as explaining, justifying, and evaluating solutions to problems.

4.4.1. Results from student diaries

The analysis of data for the quantitative question *"How was the collaboration among the team members today?"* shows (Tables 39 and 40 - Appendix 1) that students at both formal and informal pilot sites, and in both countries, answered predominantly *"very good"* (63,33% - 63,33%). In this case there is a statistically significant correlation between pilot site type and how students collaborate ($p=1{,}037e{-}006 < 0{,}05$). On the other hand, there is no statistically significant correlation between countries and how students collaborate ($p=0{,}11$) according to the Fisher exact test. This result is due to the high total number of Greek pilot sites and informal pilot sites, and apart from the positive intention of very good collaboration, not further conclusions can made from this result.

The responses to the question *"What did you like the most today?"* reveal important points regarding collaboration during an eCraft2Learn intervention. A rather high number of students commented that they liked the way they worked, in other words collaboration, teachers' methods, and so on. More specifically, a large number of positive comments were made regarding collaboration: *"Collaboration and teamwork", "team discussion about all team project and their idea", "I liked it that we worked well all together and we made something as a team", "The collaboration to find nice ideas"* as well as about the method used: *"I liked it today when we planned and made everything we needed today"* and *"I liked that we all worked together and we had a great result"*. There are some very interesting comments about the way teachers worked with students: *"I liked that we were left by our teacher to explore ourselves the solutions of some problems that emerged."* and *"I really enjoyed the collaboration we had with my team and teachers..."*. The whole environment seemed to have played a positive role since there are comments such as: *"The nice atmosphere within the team"*. Finally, it is worth mentioning that some teams really liked being part of the same team in the first and second rounds: *"Reuniting with my team's friends as well as sharing and presenting ideas with the others"*. At Finnish pilot sites, there were also highly positive comments regarding the collaborative environment that eCraft2Learn methodology promotes: *"Today I liked the most planning the team work and we were happy with the result!, because she kept me company when we couldn't do anything*", *"Working together, ……"* and *"Our awesome team spirit."*.

The second open question in the diary was *"What did you like the least today?"*. The most common response was *"Nothing"*, mentioned in 85 diaries in both rounds. Combined with *"Everything is ok", "I liked everything", "I liked all"* and other similar comments made more than 15 times, it can be safely concluded from around 95 to 100 diaries out of the 232 completed in both rounds, that the students were pleased with everything. There a rather small number of replies that brought to light the issue of cooperation. One student noted: *"I did not like that at first we could not concentrate and coordinate"*. In contrast, there were notes from students asking to work with a particular team where they had very good collaboration: *"I wanted us to be all in the same team"* or they sought for collaboration: "*That I was a bit alone"*, which means that they wished to collaborate in some way. Additional comments include: *"The bad collaboration with my classmates"* and *"the communication among students"*. Students also mentioned the serious problem of limited time: *"The fact that we only had 2 hours available for the workshop"*, which is of particular concern in any formal classroom setting. In general, students reported that they enjoyed the social aspect of the work most. All these responses can be counted in favour of the importance of a collaborative environment, something which eCraft2Learn strongly supports.

4.4.2. Results from Teacher Diaries

The answers to the quantitative question *"Share. Did the students go through this stage today?"* reveal important outcomes. The cumulative data in Table 8 (Appendix 1) illustrates that a mere 35,33% of teachers answered *"Yes"*. Further analysis using the generalisation of Fisher's exact test reveals a few interesting facts. There is a statistically significant correlation ($p=1{,}249e\text{-}012 < 0{,}05$) between the site and the perception of teachers whether students went through the stage of Share during the intervention. This statistically significant difference might be due to the very small number of *"Yes, but to a limited extent"* answers from formal Greek (1) and informal Finnish (3) pilot sites, where students mostly went through this stage. On the other hand, there is a rather important percentage of *"Yes, but to a limited extent"* answers from informal Greek (12) and formal Finnish (16) pilot sites, where a number of students did not go through this stage. Sharing is a very important aspect for collaboration in the modern web 2.0 era that includes among other things interacting effectively with others and sharing knowledge. This finding proves the step of Sharing to be related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The answers to the quantitative question *"How was the collaboration among the team members?"* reveal important outcomes. The cumulative data in Table 9 (Appendix 1) illustrates that teachers answered mostly *“very good”* (49,13%). Further analysis using the generalisation of Fisher’s exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,0018) between the site and the perception of teachers of student collaboration during the intervention. This is to be expected since the level of collaboration were not the same at all pilot sites.

The answers to the quantitative question *“To what extent are you satisfied with the progress made by your team today?”* reveal important outcomes. The cumulative data in Table 10 (Appendix 1) illustrates that teachers answered mostly *“To a great extent”* (46,71%). Further analysis using the generalisation of Fisher’s exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,0016) between the site and satisfaction of teachers with progress made by teams. This is to be expected since the level of collaboration were not the same at all pilot sites.

The answers to the quantitative question *“Where do you place your role in the workshop based on today’s experience?”* reveal important outcomes. The cumulative data in Table 12 (Appendix 1) illustrates that a little over half the teachers (52,78%). Further analysis using the generalisation of Fisher’s exact test reveals a few interesting facts. There is a statistically significant correlation (p=0,00057) between the site and the perception that teachers have about their role. This might be due to the small number of answers from Finnish sites.

When informal pilot site teachers were asked to briefly describe their role in each session, various interesting responses were given. Most of them commented that they acted as coaches: *“Coach”, “I supported the students to work on the project.”* or *“Helping"* or even “*Adequate guidance of the team for the implementation of the circuit and the preparation of the program.”*. The more detailed notes mentioned that children hesitated to work on their projects, such as *“Our role as trainers was to help. But we noticed that the children were expecting us to tell them the next step, what was an obstacle to the development of the project. So, after the initial guidelines, we let the team work autonomously and take initiatives”*. Teachers believed that they responded appropriately and allowed students to work autonomously. Some teachers provided some help with equipment: *“To bring H/W and S/W up…..”* and *“Provide the necessary tools and help with the implementation of children's ideas.”*. On the other hand, there were instances where teachers were more actively involved in the construction: *“In the creation phase I participated only in the stabilization of the sunflower. In the programming and (mainly) the circuits, I offered a lot of guidance so as to simplify the artefact and ensure the right use of the Arduino entry/exits.”* and *“I participated as a member of the team in the programming so that some problems can be fixed. As a teacher, I helped with the new electronic material that were used”*, which is not in accordance with the project aims.

In addition, in some cases teacher said that they reverted to a more traditional way of teaching: *“Teaching code using snap4arduino, explain code's logic…”* and *“I had to answer a lot of questions, explain to them why many of their ideas would not work the way they thought.”*. However, there were some instances where teachers had no choice but to be more active, as in the case of a new team formation *“I was completely involved since the students of my team were absent and I created a new team with two new students”*. This situation seems to be the same at the formal pilot site since teachers answered that they acted as instructor, coordinator and problem-solver most of the times, which is rather different from what eCraft2Learn wishes to inspire. Furthermore, it was also mentioned that they acted as assistants (quite a few times) supporters, helpers, facilitators, mentors and even observers, which are more in alignment with eCraft2Learn teaching methodology.

There were also some teachers at the formal Finnish site who were familiar with the idea of coaching before starting the eCraft2Learn projects. Also mentioned was the active role in the ideation phase and engineering problems in particular. The teachers gave students plenty of responsibility in their work and allowed them to be the main actors in the classroom, focused on encouraging students and supporting them on how to start solving problems.

The question *"Did you learn something new from your interaction with the students today?"* in student diaries, offers an opportunity to gain an insight into any collaboration advancement in the eCraft2Learn ecosystem. The teachers seem to recognise the value of collaboration in the context of making projects and the need to encourage collaboration and teamwork. They also realised that the students can cope with highly demanding projects when working collaboratively and with the appropriate level of support (when necessary). Notably, the support can come from the teachers, fellow team members, or both. The formation of solutions can occur collaboratively as well as through creative discussions, considerations and reconsiderations, arguments and testing. Furthermore, there were some interesting diary entries about teamwork such as these ones about self-regulation: *"That the team has to auto-regulate, even if this is time consuming"*, *"The importance of a good team"* and *"Disagreement sometimes can be creative".*

4.4.3. Results from Observation Forms

The answers to the quantitative question for the Share stage reveal important outcomes. The cumulative data in Table 17 (Appendix 1) illustrates that observers predominantly answered *"No"* at three pilot sites (83,33%, 84,85%, 70,48%) and only at the informal Greek pilot site (Technopolis) did they mainly respond with *"Yes"* (53,97%), since they allocated time for sharing intensively. Further analysis using the generalisation of Fisher's exact test reveals a few interesting facts. There is a statistically significant correlation ($p=2{,}025e\text{-}011 < 0{,}05$) between the pilot site and the perception of observers that students went through the Share during the intervention. Sharing is a very important aspect of collaboration in the modern web 2.0 era and, among other things, include interacting effectively with others and sharing knowledge. This finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

4.4.4. Results from Interviews with Teachers

Teachers reported that the pilots had **affected the group dynamics**. Teachers agreed that (mostly) all students were actively working on the project in order to fulfil their plans and goals.

"It was great to see that all students were working. And could find their role in the group." (Teacher E, FIN)

“There is a risk in this kind of a [project based] learning that there are free riders. But in this project there was nothing like that.” (Teacher D FIN)

“I think they [students] worked very well in the beginning, before that and after that, well after that maybe even better. Here in a class I have seen a few girls who - well in my opinion - don’t do anything, just sitting and doing something else [than the project] but they were very interested in making the flower.” (Teacher A, FIN)

Some interviews with teachers revealed that especially (some) boys, though in normal school work are more quiet and stay in the background, **improved their self-confidence and courage** when they actively took responsibility for working with electronics. Thus, some changes in the student behaviour were observed during the project.

The teachers identified multiple benefits of the type of project-based learning that eCraft2Learn projects represent and observed that this process is a graduate development (teacher A, GR). Especially **impacts on students’ abilities in collaboration skills,** in combination with methodological skills, **allowing creativity** and learning programming and robotics were mentioned as this project provided a small insight into technology. Teachers saw the value of having these skills in the future. They also found eCraft2Learn projects to be a great way to **open up a new perspective to the real world**; where technology actually is and how it helps us every day.

“When they have the courage to take responsibility for the work and they want to do it well. Taking the leader’s role in the team. That is something students do not get anywhere else in the school work.” (Teacher C, FIN)

4.4.5. Results from Interviews with Students

Many students emphasized teamwork as a valuable learning experience.

“[...] The workshops were an extremely valuable experience due to the fact that I learned to be part of a team and co-operate with other persons [...] “(Participating student, GR)

They enjoyed working in teams: *“Working in teams was the major difference” and “[...] but after a while a team of the three of us was formed. I think we immediately matched. We comprehend each other and we helped each other with the robots.” (Participating student, Athens, GR)*

When asked what the students enjoyed most, they mentioned team spirit and the lack of competitive atmosphere: *“The team spirit. There was no competition among us as to who is best.” (Participating student GR)*

4.4.6. Results from Final Student Questionnaires

The analysis of data for the quantitative question *“During the workshop I was able to plan and coordinate with others.”* shows (Tables 27 and 28 - Appendix 1) that students at both formal and informal pilot sites, and in both countries, answered predominantly *“Yes”* (81,82% - 81,82%). In this case there is a statistically significant correlation between pilot type and whether students were able to plan and coordinate with others (p=0,012). On the other hand, there is no statistically significant correlation between countries and whether students were able to plan and coordinate with others (p=0,7) according to the Fisher exact test. Sharing is a very important aspect of collaboration in the modern web 2.0 era and, among other things, include interacting effectively with others and sharing knowledge. This finding illustrates that this step is related to the pilot site of the intervention. This may stem from the mentality, the way of working, and/or the tutors of the pilot.

The analysis of the data for the quantitative question *"During the workshop I was able to do the things the way I preferred."* shows (Tables 25 and 26 - Appendix 1) that teachers at both formal and informal pilot sites, and in both countries, answered predominantly *"Yes"* (60,39% - 60,39%). But in this case there is no statistically significant correlation in either cases, neither for pilot site types (p=0,16), nor for countries (p=0,32) according to the Fisher exact test. This can be explained by the eCraft2Learn environment providing an open environment that fosters freedom in decision making as well as the evaluation of information gathered from, or generated by, observation, experience, reflection, reasoning, or communication irrespective of the pilot site.

Regarding the question *"Any other thing that you feel more comfortable doing than before? If so, what?"*, there is a very important finding that students felt more comfortable with aspects such as collaboration and social interaction within a team or the class. In particular, they mentioned that they felt comfortable *"Being an active member of a team"* (1st session), *"to meet my team", "Never give up" and "to present publicly"*. One student said that what they liked the least was *"When I couldn't take part of our group when two people could do the project, and even though we were just trying to help, they excluded us from the group"*, and another student mentioned *"That I wasn't allowed to program"*. This indicates that teachers as coaches should assist the students to develop their teamwork and collaborative skills, particularly when students are not used to working together, as to avoid feelings of exclusion and frustration. These examples indicate a wide range of impacts of the pilots on the students regarding knowledge, confidence and capabilities.

4.4.7. Collaboration Skills Validation: Conclusions

In this subsection, the key findings that validate the claim about the fostering of collaboration and teamwork skills through the eCraft2Learn ecosystem are summarised. To begin with, the students stated that the eCraft2Learn workshops contributed significantly to the development and/or improvement of their teamwork skills. Collaboration was predominantly described as *"very good"* (63,33%). Notably, many students maintained that through the eCraft2Learn collaborative and sharing context they felt more creative and productive. However, the sharing aspects (as emerged from the feedback retrieved by the teacher) can be further enriched for maximizing learning outcomes.

The eCraft2Learn ecosystem also seems to foster (apart from student-student) also teachers-student collaboration. Teachers mentioned that they enjoyed acting as coaches by the side of the students no matter how straightforward this was for everyone (see also D5.2). The teachers assisted the learning process and took on several roles, that of supporter, helper, guide, mentor and even observer; these roles have a place in the eCraft2Learn ecosystem and are in alignment with the eCraft2Learn pedagogical model. In addition, the teachers mentioned that through their collaboration with the students they learnt new things and they discovered ways to better support them.

The evaluation tools that supported the validation of the claim related to collaboration are: student diaries, teacher diaries, observation forms, interviews with teachers, interviews with students, and final student questionnaires.

4.5. ECRAFT2LEARN TECHNICAL ENVIRONMENT FOR THE CRAFT- AND PROJECT-BASED LEARNING PEDAGOGY VALIDATION

In this section we present the analysis of the findings that validate the claim according to which the eCraft2Learn technical environment supports craft- and project-based learning pedagogy. The results (derived from several data collection tools) aims at checking the validity of the claim by identifying signs that show whether the eCraft2Learn technical environment supports craft- and project-based pedagogy. The focus on whether the eCraft2Learn tools and technologies supported creative engagement in projects, making practices, access to resources and the development of shareable computer-supported artefacts.

4.5.1. RESULTS FROM STUDENT DIARIES

The responses to the question *"What did you like the most today?"* is of great importance to usefulness of the eCraft2Learn technical environment as a supporting backbone to the craft- and project-based learning pedagogy. The responses to the aforementioned question revealed a variety of points. Most of the students commented that they liked everything and a significant number that they gained knowledge that is closely connected to projects and craft. There were positive remarks regarding knowledge of circuits and especially about *"Circuit construction"* and *"I learned how to connect lots of parts on breadboard"*. Positive comments were made about Arduino and Raspberry Pi, which were the main tools of each project. Students stated that: *"I liked that they showed us how to connect several cables with Arduino and Raspberry and how to make a LED light work, with these materials"*. Knowledge of various project based constructions, mainly robots and artefacts, were the most popular constructions among students: *"I like the most the construction of robot ring."* and *"That I can build an autonomous artefact"*, taking into account the construction time factor of a project *"I liked a lot when we made another robot in half an hour."*. Students also liked the distinct lesson format: *"The freedom that we had in making our designs and constructions".*

Apart from the abovementioned, the craft part in general, with students mentioning that what they liked the most was *"Crafting"*, *"Crafting is fun! Everything was fun. It was nice that we got our plan done."* and *"Combining lights and crafts"* as well as 3D printing use *"A model of a palm tree that we made for 3D printing with a computer"*. Students positively referred to 3D printing with comments such as *"How 3D printer draws"*, *"I liked a lot that we print something in 3D printer."* and others illustrated their strong interest in 3D printing. Finally, students mentioned some of their achievements, which are a combination of project and craft, such as *"I liked that we made an interesting construction and made it very complicated."*, *"I liked that we managed to make the sunflower after lot of effort."*

and *"It was fascinating when we were making noise over the threshold the rabbit was hiding."*, which can be interpreted as students recognizing and dealing with the difficulties of the project and evaluating the final outcome.

Furthermore, in order to support the project and craft pedagogy it is very important to have good teamwork, collaboration and an open environment. A great number of student comments are about what they liked, focusing on the way they worked, in other words collaboration, teachers' methods, and so on. More specifically, a large number of positive comments were made regarding collaboration: *"Collaboration and teamwork", "team discussion about all team project and their idea", "I liked it that we worked well all together and we made something as a team"* and *"The collaboration to find nice ideas."* as well as about the method used: *"I liked it today when we planned and made everything we needed today."* and *"I liked that we all worked together and we had a great result."*. There were some very interesting comments about the way teachers worked with students: *"I liked that we were left by our teacher to explore ourselves the solutions of some problems that emerged."* and *"I really enjoyed the collaboration we had with my team and teachers..."*. The pedagogical environment was a place where students could feel free and foster their abilities with new knowledge: *"The nice atmosphere within the team"*. This leads to the phenomenon that some teams really liked being part of the same team in the first and second rounds: *"Reuniting with my team's friends as well as sharing and presenting ideas with the others"*.

In terms of what they liked least, some students referred to the teaching methods. The most noteworthy comments are: *"A very theoretical part that made the lesson slow, in my opinion"* and *"Continuous repetition of recycling of ideas"*, which differ from the target of the project. In addition, the comment *"at the begin I did not understand what to do (connections, breadboard, Arduino etc.)"*, indicates that the eCraft2Learn framework needs improvement in order to be understandable to all possible users.

Furthermore, students noted down some achievements that they believed were not attained, such as: *"All went well, we simply did not manage to complete the program so as to deal with the construction the next time.", "I liked less that we did not manage 100% to make the led blink every few seconds.", "We did not manage to implement the project with the camera and the microphone."* and *"We did not manage to make the robot to move."* and also conveyed some technical issues that they faced: *"I did not like the fact that the microphone did not work with the programming."*, *"Programming"* and *"I did not like that we could not connect to Tinkercad."*. Sometimes technical issues disappointed students: *"That nothing worked"*. There were several comments and concerns about Raspberry Pi in some tests that they had to perform, which caused frustration: *"That raspberry was crashing too much and made programming too slow because we had to"* or "*That the PC crashed"*. Special reference was made to AI programming: *"The fact that Snap4Arduino could not respond to the program. Also, Raspberry could not recognize the camera, so we never get this done."* which seemed to have a problematic application in the first attempt. Nevertheless, the problems related to achievements compared to the positive experiences are slight.

The replies to the question *"Do you think that you learnt something new? If yes, could you please refer to what you learnt?"* in student dairies contributed to the usefulness of the eCraft2Learn technical environment as a supporting backbone to the craft- and project-based learning pedagogy. Apart from *"Nothing"* being the most common response, there were plenty of examples of new knowledge that students mentioned gaining, for instance: *"A lot of things about raspberry and for programming generally",* about robots, sensors, microphones, Arduino: *"I learned how to connect many parts with Arduino like LEDs, buttons and monitors"*, *"I learned how to melt zinc and combine a led to a cable"*, *"Draw 3D and print 3D"*, *"I learnt about Cura"* and *"connection on a breadboard"*, about photo resistors: *"How to program a car"*, and knowledge about programming: *"I gained a lot of knowledge about programming"* and *"I learned programming at Snap4Arduino"*, as well as about electronics: *"I learnt to control the blinking rate/rhythm in the led", "I learned about speakers connection and motion sensor", "I learned about the L293D amplifier and for mini bread board"* and *"Use of App Inventor, Raspberry"*. These capabilities are of too wide a range to cover a full project based construction, including crafting. The best proof of projects is the description of each project in D5.4.

4.5.2. Results from Teacher Diaries

Teacher questionnaires include a question about project description. The variety of projects that students did, according to their teacher's description, illustrates that the eCraft2Learn technical environment is supportive for the students. These support the statement that the eCraft2Learn technical environment is supportive of the backbone to the craft- and project-based learning pedagogy in that students were fairly creative regarding the variety of projects that they aimed to construct. In both countries, and at both formal and informal pilot sites, teams materialised project ideas such as a security alarm system with three zones using a distance sensor and LED lights for the alarm notification, a control system with photoelectric sensors, a robot with a distance sensor, a robot that follows light, an autonomous robot using Raspberry Pi without Arduino, a car with a distance detector, and a fully functional bridge at the formal Greek pilot site which combines electronics and 3D printing. The ideas from students at the informal Finnish site included a high five robot, interactive art, motion detector projects such as a head and a lighting system in a house, a robot head and smart homes. These are quite indicative constructions of the craft- and project-based ideas that students worked on during the eCraft2Learn intervention.

When informal pilot site teachers were asked to briefly describe their role in each session, they provided indicative responses of how the eCraft2Learn technical environment supports the craft- and project-based learning pedagogy. There were various interesting answers, most of which alluded to teachers acting as coaches: *"Coach", "I supported the students to work on the project."* or *"Helping"* or even *"Adequate guidance of the team for the implementation of the circuit and the preparation of the program."*. The more detailed notes mentioned that children hesitated to work on their projects: *"Our role as trainers was to help. But we noticed that the children were expecting us to tell them the next step, what was an obstacle to the development of the project. So, after the initial guidelines, we let the team work autonomously and take initiatives"*. Teachers believed that they responded appropriately and allowed students to work autonomously. Some teachers provided some help with equipment: *"To* *bring H/W and S/W up…..”* and *“Provide the necessary tools and help with the implementation of children's ideas.”*. On the other hand, there were instances where teachers were more actively involved in the construction: *“In the creation phase I participated only in the stabilization of the sunflower. In the programming and (mainly) the circuits, I offered a lot of guidance so as to simplify the artefact and ensure the right use of the Arduino entry/exits.”* and *“I participated as a member of the team in the programming so that some problems can be fixed. As a teacher, I helped with the new electronic material that were used”*, which is not in accordance with the project aims. There were also some teachers at the formal Finnish site who were familiar with the idea of a teacher as a coach before starting the eCraft2Learn projects. They described instructing, helping and guiding the students in their learning processes. Also mentioned was the active role in the ideation phase and engineering problems in particular. The teacher gave students a lot of responsibility for their work and allowed them be the main actors in the classroom, focusing on encouraging students and giving them support on how to start solving problems. The approach of teachers acting as tutors is akin to the position of a project manager, and in this way students enjoyed the experience of being project members and acting within a team with a set of tools (resources).

4.5.3. Results from Observation Forms

The observation form tool supports the claim that the eCraft2Learn technical environment is useful as a supporting backbone to the craft- and project-based learning pedagogy in terms of the responses to the prompt *“Educational resources used by the teachers/coaches (i.e. videos, web-links, print-outs, etc….):”*. The responses of observers at Greek pilot sites, mentioned that students used YouTube videos, online images, online information, paper-based sketches, worksheets, printouts, paper, pairs of scissors, glue, silicon, LEDs, resistors, Arduino, Raspberry Pi, servo motors, sound sensors, motion sensors, handcraft, working sheet, speakers, led, wires, pictures of the L293 chip, Sparkfun video with motors, distance sensors, Snap4Arduino, Ardublock, Tinkercad, Cura, Snap4A web version, AI blocks, microphones, videos, web searches, and UUI.

At Finnish pilot sites, teachers did not provide as many educational resources in the first round as in the second round. Thus, the first round experiences helped teachers to realize where students would especially need guidance and how they could provide support for students with different educational resources. In general, the resources were provided mostly at the beginning of the new projects and then the instructing and coaching was more tailored for each student team without using extra resources. As *“Educational resources used by the teachers (i.e. videos, web-links, print-outs, etc….):”* during both rounds, teachers were giving oral and written instructions on how to proceed during the lessons. For example, one teacher wrote three tasks on the board (3D modelling, wiring the Arduino or programming) from which student teams could choose the ones they deemed important for their own project. This fostered their self-regulatory skills. Teachers also presented examples of other eCraft2Learn creations of possible sensors that students could use, showed pictures and gave key search words to find Arduino circuits, provided web links for students to find information and gave short introductory lessons or hints about 3D modelling and printing as well as Arduino wiring and Snap4Arduino programming. One teacher also brought his own 3D-pens from home for the students to use in their projects and showed videos of how to use these pens. Especially during the second pilot round, these introductory lessons were conducted as slide show presentations that not only included basic instructions on Arduino wiring and programming, but also introduced the UUI and the topic to be studied during the projects. Teachers had also created a few files to help students to plan their projects more carefully (which kind of materials and sensors to use, how to implement AI in the projects) as teachers noticed during the first pilot round that the ideation and planning stages were somewhat challenging for students. For the usage of AI blocks, two teachers had created an AI example in Snap4Arduino that student followed and learnt in order to read and understand the code.

As far as the overall workshop impressions are concerned, we observed a positive working atmosphere. The teams were working on their projects without any problems. We also observed that for every piece of equipment provided during the session, the teams assumed it was for immediate use, but when they had problems with certain tools students invented new tools. Adding to this is an observer comment that conveys *“Very positive impressions”*. The students were very creative, working in a real making environment. Some students asked to extend the workshop or even to skip the Math class at a Greek formal site, in order to continue working on the project. The teachers were surprised to see how much the students were into crafting. Some students were more into programming, while others preferred soldering, wiring and crafting. In general, students seemed to have been enjoying the hands-on constructions and the fact that teachers were not acting as traditional teachers. The students were many and thus teachers took on a supportive role; they were looking for solutions together with the students, for resources online (e.g. wiring diagrams) and also explaining to the students that they did not have ready-made solutions, but that they could explore any emerging problems together. The resources/guidelines provided during training were considered very useful, as they could be adapted to different variations of problems. Time appears to be a critical factor, as referred to in diaries. It was encouraging that the atmosphere remained positive, pleasurable and creative as the project got progressively more complex, and with the team observation becoming more difficult.

Regarding needs emerging (if any), the students and the teachers took pictures of their artefact constructions. They kept asking how they could share these videos and photos. *"Where can we upload them?"* and *"How can we share our work and the progress that was made?"*. It was mentioned that Snap4Arduino and Arduino IDE were very slow, as well as that microphones did not work. Furthermore, problems arose with a microphone sensor as well as some Raspberry Pi crashes. The teachers and students also had ideas for new materials for crafting (i.e. playdough). It was difficult to observe what exactly was going on in each team as each team progressed at a different rate. In addition, at times more materials, particularly electronic components, were required for the construction stage.

Students and teachers needed help and instructions on how to wire different sensors and actuators with the Arduino and especially on how to program the Arduino using Snap4Arduino. It is relatively easy to find different Arduino circuit diagrams online but the program codes for Snap4Arduino are trickier and here students were not able to proceed independently without teachers’ help. Perhaps some library or repository of pictures about basic program codes would facilitate this part of the project for both students and teachers. This would assist students in catching up with what was done during the previous sessions and foster their self-regulatory learning. Also, for the 3D modelling itself, it was noticed that a number of students were disappointed with their 3D printed items. Students often wrongly assume that the item would be bigger and show all the details but in actual fact the printer cannot print everything because of the nature of the model. When students used a model from the ready-made models, the printer usually performed better. Perhaps students could use some other 3D modelling software rather than learning how the model should be designed and understanding how the printer can actually print.

4.5.4. Results from Interviews with Teachers

Several teachers could see many advantages in using the UUI. It seems that the technical environment can support students while involved in making. Electrical circuit making, 3D modelling and printing seem to have been significantly supported through the UUI. There are also references to the UUI making it easy to access educational resources and encouraging students to self-regulate their learning.

> *"It guides students to be more self-regulated. And it has everything needed. It is a very complete package for Arduino and 3D printing." (Teacher D FIN) and "This platform makes it easy to search and find information." (Teacher D, FIN)*

Additional advantages are related to the fact that everything is gathered in one spot and the coach can choose what serves or suits him/her best. Some teachers expressed the view that it would be beneficial to record the students' actions so as to have some statistics and feedback on the progress that is made. This comment directly points to the integration of the **learning analytics tools** into the UUI, which are seen by the teachers as something ***necessary and useful***.

Lastly, nationwide benefits for the use of the UUI in the Finnish school setting were also identified and were closely linked to the contextual way the eCraft2Learn technical core supports engagement in programming.

> *"Now when programming is mentioned in the Finnish curriculum, this what UUI provides is a very good help for both teachers and students to start exploring and testing. It is a great base where to start programming and making robots." (Teacher D, FIN)*

4.5.5. Results from Interviews with Students

It is worth mentioning that many students when interviewed highlighted the access to a variety of tools and materials for completing their projects. The students referred to the materials that were available tools and technologies (hardware and software) that were available through the Unified User Interface highlighting the fact that the options were many and that they could freely make their own choices. The fact that they could also decide on the materials to use based on their preferences (i.e. wood, recyclable material, paper and more) was also highlighted by the students.

"[....] we had the opportunity to use whatever material and to select among different programs freely… and that is what we liked it! We didn't have someone to tell us how to do things [...]" (participating student, GR)

"...once we were provided with the necessary materials, we managed to adjust the robots to our needs… it was a unique experience!" (Participating student, GR)

Last, the students commented positively on the way the workshops were carried out emphasizing the direct use of the available tools and technologies for testing and project implementation. Theoretical knowledge was mainly gained through practical and hands-on engagement with the different aspects of the project.

"...We didn't have a predefined pattern, meaning teaching theory for 30 minutes and practicing for up to 15 minutes. We had the equipment and we were testing everything immediately. If we had any problem we were asking our coach" (Participating student, GR)

4.5.6. Results from Final Student Questionnaires

The second open question *"During the workshop I liked most:"* drew the most responses from students. A significant number of answers referred to programming environments that they liked such as AppInventor, while there were some positive comments about electrical circuit making with Arduino boards and units and also positive comments about 3D printing practices.

"I liked most programming and 3D printing" (Participating student, GR)

In addition, the students highlighted the way of working in the pilot projects, the availability of the eCraft2Learn tools and technologies, the use of simple materials towards computer-supported artefacts constructions, and the process of working on their projects (even when facing problems and difficulties) in order to achieve their goals.

"I liked the way we were working in this project". (Participating student, GR)

"I liked the most that I was learning and facing new things. Also the opportunities we got!" (Participating student, FIN)

"I liked the fact that the realization of each project was done with simple daily materials ..." (Participating student, GR)

On the other hand, the purpose of the question *"During the workshop I liked least: "* was to identify issues that the majority of students may not have liked, and in one way or another, they mostly said *"Nothing"* (33 out of 41). However, a few comments were documented that were related to technical problems that were experienced during the pilots. Crashes, delays, malfunctioned sensors are among them.

"The PC was rather slow". (Participating student, FIN)

"Sometimes electronics would crash and I was tired of making a reset." (Participating student, GR)

"At some of our meetings I did not like the fact that we had problems with the microphone or that the Raspberry crashed". (Participating student, GR)

"Sometimes we encountered difficulties that made us nervous, like the slow internet connection" or students were disappointed when they had troubles with the electronics or when they didn't know how to proceed or had to solve problems". (Participating student, GR)

4.5.7. eCraft2Learn Technical Environment for the Craft- and Project-Based Learning Pedagogy Validation: Conclusions

The students mentioned that throughout the workshops they had good access to a variety of technical tools that were exploited for hand crafting and creating their projects. There were many positive comments related to the freedom that they had in using the available eCraft2Learn tools, technologies and resources in order to make their own designs and constructions. Students emphasized their engagement in hand crafting, and in electrical circuit making and programming. They also highlighted their engagement in 3D printing activities. Furthermore, the opportunities provided to share good practices and ideas and collaboration with one another were also highlighted by the students.

As far as the access to educational resources is concerned, this was achieved through the UUI covering many different aspects of the making projects (i.e. electrical components, wiring connections, AI programming, use of sensors, 3D printing and more). The teachers highlighted the importance of the educational resources (both technical and pedagogical) for supporting student engagement in craft and project-based learning practices. The teachers created additional educational resources to help students start working on their projects (in there information was documented regarding ideas for projects, the kind of materials and sensors that can be used for specific projects, how to introduce AI in the projects and more). These resources were mainly used at the beginning of the pilot for familiarization purposes and can guide additional students and/or newcomers to the eCraft2Learn ecosystem to start working on their own computer-supported artefacts.

Overall, it seems that the technical environment was found useful to support the eCraft2Learn pedagogical model, providing opportunities for ideation, planning, creation, programming and sharing. Students and teachers had access to a variety of tools and resources that could be used to produce shareable computer-supported artefacts. The students were able to choose the material, tools and the technologies that could support their constructions. There was no predefined path to follow; just a constructionist and iterative format that encouraged the implementation of projects interdisciplinary in nature in the fields of Science, Technology, Engineering, Arts and Math (STEAM). In this constructionist and iterative format, the students were observed to go through multiple processes: from idea generation, to planning, to collaborative hands-on construction, to problem solving, reflection, sharing, re-designing and re-construction. All these processes were interwoven in the eCraft2Learn pedagogical model and learning methodology and reflected in the eCraft2Learn technical core/environment.

The evaluation tools used to validate the aforementioned claim included: student diaries, teacher diaries, observation forms, and interviews with teachers, interviews with students and final student questionnaires.

4.6. Contributing to the Validation of the Claims: Teacher Narrative Reports

After the completion of the pilots, the eCraft2Learn project team had the chance to interact with the participating teachers. During these interactions, teachers stated that they had observed positive changes in their students' behaviour and attitudes which were not noticeable before or during the period where the interviews for impact measurement were being conducted (see D5.4). These statements led to the development of a template for a narrative frame with four (4) questions that could potentially help teachers document their experiences more formally and post pilot reflections in a narrative form. The template (see appendix 2) was sent to the teachers for optional completion.

In total, 4 narrative forms were collected by mid-November 2018 that present cases where a positive change (closely linked to the eCraft2Learn experience) in students' behaviour and attitude was noticed post pilot completion. This does not mean that there are no additional students who were positively affected; this simply means that by mid-November 2018, four (4) cases were observed and relevant reports were written by the observing teachers. Notably, changes in behaviour or the attitude do not readily occur while a learning intervention is in progress and there is no guarantee that changes will happen directly after the intervention or that they will be maintained long term.

The first narrative form received was from a teacher from the eCraft2Learn informal pilot site in Athens (Greece) that happens to be an active educator in the Network for Children's Rights in Athens[2] (see also D5.5, page 17). The informal teacher referred to *Student A* who is also involved in the Network of Children's Rights. The teacher provided a brief profile of the student before his participation in the eCraft2Learn pilots. He then highlights positive changes that were observed in his behaviour and attitude that are directly linked to his engagement in the eCraft2Learn learning ecosystem.

> **Student A: Brief description of the student's profile before engagement in the eCraft2Learn pilots**
>
> *'Student A is 17 years old, comes from Pakistan, and attends the educational program of the Network of Children's Rights and lives in a host house for unaccompanied children. During the period 2017-2018 we* [meaning: the educator and a colleague of his from the Network of Children's Rights] *were looking for educational activities in which he could participate. Given his interest in robotics and programming, he happily agreed to participate in the eCraft2Learn workshops. He was not very talkative and rather reticent. He was mainly using English to communicate, despite the fact that he could also understand and speak Greek'.*
>
> **Student A: Signs of change (during or after the eCraft2Learn pilots)**

[2] Network for Children Rights official website: https://ddp.gr/?lang=en_gb

'After his participation in the eCraft2Learn workshops, we [meaning: the educator and a colleague of his from the Network of Children's Rights] *started recognising positive changes in his behaviour. He was becoming more self-confident and more social. More precisely, while in the beginning was not a very active member in the team, he gradually took on a more active role, worked well with the other three team members and was even engaged in friendly discussions with them in Greek. The transition from English to Greek was important as in general he was very reluctant to communicate in Greek. The other team members contributed significantly to this as they were very supportive from the beginning and willing to communicate in English in order to facilitate his engagement in the team. He was also very interested in participating in the Athens Science Festival (ASF) with his team and presented his work in public. His interest in participating in the ASF was actually the first positive sign; during the 2nd pilot we confirmed all these positive changes in his behaviour as he was much more confident in communicating with other young students, in carrying out key tasks towards the completion of the project and in working with others in order to achieve this goal. We were pleasantly surprised when, after the 2nd pilot, he presented to us his ideas for the establishment of a robotic team in the Network of Children's Rights. During the summer he worked closely with 2 more students and they succeeded in organizing a creative team to introduce other students of the Network to the basics of robotics.*

Three more narratives were received by a formal school teacher that has been actively involved in the deployment of formal pilot studies in Greece. The formal teacher referred to three students (Students B-D); their profiles differ but they were all seen to adopt new behaviours and to negotiate teamwork and collaboration, ultimately forging their own way to effectively work with others. Interestingly, the eCraft2Learn ecosystem appears to support Student B in realizing the value of sharing ideas, accomplishments, experiences and struggles with each other and in developing teamwork skills transferable also outside the school settings.

Student B: Brief description of the student's profile before engagement in the eCraft2Learn pilots

'Student B is a smart, adept, and social 17 years old with many interests and good grades in school subjects. He has difficulty in concentrating on a common goal, in working with others and quite often his behaviour towards his classmates or his teachers is deceptive'.

Student B: Signs of change (during or after the eCraft2Learn pilots)

'After the pilots, I realised that the positive attributes of his profile were enhanced while at the same time he started being more open-minded as far as respectful collaboration is concerned. During the pilots, while he was working on the computer-supported artefacts, he realised that he needed others in order to move forward and to share ideas. Now he is working more effectively with others. He has even bought equipment and continues his constructions at home in collaboration with some teachers and classmates. I think that the eCraft2Learn ecosystem is

open; it does not enforce boundaries and encourages you to find your way towards constructions as well as your way in working with others'.

The narrative that was reported for student C is presented below. An interesting aspect in the following narrative is that the eCraft2Learn ecosystem appears to support students' creative skills and competences and to help them develop a sense of themselves and their individualities within a sharing context.

Student C: Brief description of the student's profile before engagement in the eCraft2Learn pilots

'Student C is 17 years old. He obtains average grades at school, is kind and too shy to speak up in class. He rarely expresses his opinion and let's his classmates speak for him'.

Student C: Signs of change (during or after the eCraft2Learn pilots)

'After his participation in the eCraft2Learn workshops, I realised that he became more extroverted, he was participating more and his school grades slightly improved. During the workshops, I could not clearly see the positive signs. His participation in the Athens Science Festival as a presenter was a pivotal point. His classmates and I realised that this was an opportunity for him to use his creative skills in photography and video making in order to provide visitors with a positive experience and to better present the artefacts. During the festival, I enthusiastically realised that he had agreed to be interviewed and to speak about his experience as part of the eCraft2Learn team. Since then, he has actively taken initiatives in creatively supporting the presentation of eCraft2Learn projects at events at our school and elsewhere (e.g. at the STEAM Night event). I think that the eCraft2Learn ecosystem helped him realise his strengths and skills and encouraged him to use them with confidence and further build upon them'.

The narrative for Student D is presented below. An interesting aspect in the following narrative is that the eCraft2Learn ecosystem appears to support craft and making practices (linked to the 4th and 5th claim) in a sharing context that can inspire and motivate students towards acting collaboratively and communicating effectively with others.

Student D: Brief description of the student's profile before engagement in the eCraft2Learn pilots

'*Student D is now 18 years old. She used to underperform at school and in the past she had exceeded the absence day's limit. At school, she was usually very loud, difficult to work with and often expressed her dissatisfaction of the learning processes.*

Student D: Signs of change (during or after the eCraft2Learn pilots)

'From the beginning of the workshops, she showed a keen interest in crafting and constructions and great enthusiasm in participating in the events. She started establishing better relationships with her classmates and during that period her school performance improved

considerably. She became more supportive of others; she started making suggestions and taking initiatives related to participation at public events. This year her school grades still need improvement, but she has now developed better relationships with her classmates. I think that the changes in her behaviour are closely related to the fact that the eCraft2Learn project provided opportunities for hands-on constructions that were interesting for her, teamwork and the sense of belonging to a team. Lastly, the whole concept was to present and to share your work and this was rather motivational for her'.

It is worth noting that the narrative reports provided above cannot be easily or readily generalised. These observations and reflections were made and self-reported by the teachers that participated in the eCraft2Learn pilots and positioned themselves in the eCraft2Learn learning ecosystem. As such, they may be prone to observer bias, despite any attempts made to address reflexivity. Nevertheless, these narratives offer a rough description of participating teachers' actual experiences and thoughts. As that they cannot be ignored, they should be corroborated with the data collected by the students through additional data collection methods (see sections 4.1 and 4.4). In this respect, it can be stated that the aforementioned statements contribute to the validation of the claim according to which the eCraft2Learn ecosystem provides students with opportunities to **work creatively with others,** supporting the development of **21st century skills** related mainly to **creativity and collaboration.**

4.7. Contributing to the Validation of the Claims: Parents' Perspective

During the project implementation period, the eCraft2Learn team had the chance to interact with some parents of the participating students. It was interesting to see how the parents perceived the eCraft2Learn initiative and whether they recognised any positive effects of the eCraft2Learn learning experience on their children. As such, the parents were prompted to provide voluntary feedback and comments. Two (2) statements were collected during the eCraft2Learn event at the 2018 Athens Science Festival. More precisely, the parents of the participating students were present at the Athens Science Festival in order to attend the festival and the students' presentations. Without putting pressure on the parents, the eCraft2Learn team encouraged them to share their feedback and thoughts regarding the eCraft2Learn workshops. Their comments and feedback were video recorded (see also D6.4). Five (5) more statements were received at a later stage through email (in written format) in the context of the regular communication that the eCraft2Learn team had with the parents. These written statements were in response to the project team's request (during the Athens Science Festival) for feedback and comments regarding the eCraft2Learn workshops and the benefits (if any) for their children. In total, seven (7) statements/comments were collected; these were analysed in a qualitative way and are presented below.

Presentations of the findings and relation to the claims

All the statements received by the parents of the participating students reflect parents' satisfaction regarding their children's engagement in the eCraft2Learn workshops. Drawing upon their satisfaction, the parents provide information about their children participating in the eCraft2Learn workshops; they are referred to the skills and the benefits that their children gained and in some cases they call for a continuation of the workshops. The parents' statements (which should be seen in conjunction with the analysis that has already been carried out towards impact measurement on learners (D5.4) strengthen the points that have been raised so far (see sections 4.1, 4.3, 4.4), contributing to the validation of the following claim: "The eCraft2Learn ecosystem can foster the development of 21^{st} century skills for youth". Among the skills that are highlighted by the parents, besides cognitive skills, are learning skills mainly related to **collaboration/teamwork, problem-solving and creativity.**

Almost all the parents that provided their feedback through short statements mention the direct impact that the eCraft2Learn initiative had on their children's teamwork skills. The parents closely connect the eCraft2Learn learning experience with the development of **teamwork** skills and students' enhanced ability to work effectively and respectfully within their team or in diverse teams.

> *"My child was definitely benefited by the eCraft2Learn workshops […].He developed skills in communication and collaboration and learnt how to work with others in a team and present his work to the public" (Mother of participating student A)*

Coupled with this, the eCraft2Learn ecosystem is seen to enhance social competencies such as conflict resolution.

> *"She came in contact with other young learners (younger and older than her) who share the same interests […]. She learnt how to work in a team and solve emerging problems and conflicts collaboratively". (Mother of participating student B)*

An important issue that is stressed by the parents is related to the **constructionist format** of the eCraft2Learn ecosystem that triggers students' **imagination**, encourages **creativity** and **ideation** and moves beyond ready-made solutions and shallow knowledge. This is exemplified by the statements below:

> *"The children gained a lot of things because this project provides the foundation upon which they can ignite their imagination and develop good ideas. They learned to use their imagination... Nowadays they are offered pre-fabricated and ready for consumption concepts which don't help them develop their imagination, and therefore they do need inspiring projects like this. […]" (Mother of participating student C, GR)*

> *"[…] He used his imagination and constructed new knowledge. He was given opportunities to see his construction from multiple perspectives, to be innovative and to develop his social skills". (Mother of participating student D, GR)*

The constructionist format of the eCraft2Learn ecosystem embraces failure and mistakes and views them as opportunities to learn; the parents seem to recognise this by highlighting the **persistence** in achieving the desired outcome as an important skill that was practiced by their children.

> *"He gained collaborative values, social skills, the ability to lead and keep trying no matter the mistakes and difficulties. Apart from this, my child gained technical and programming skills". (Father of participating student E)*

If "failure" has a place in the eCraft2Lean ecosystem, then the same applies to the mechanisms for fostering problem solving. This is also recognised by the parents, enhancing our claim that the eCraft2Learn ecosystem has the potential to foster problem solving skills. The parents highlight their children's engagement in problem-solving practices, in the critical analysis of problems, formation and implementation of a solution either individually or in teams.

> *"My daughter gained skills as she worked methodically on problems and suggested solutions related to the construction of her project and she presented the project at the science festival […]" (Mother of participating student F)*

Notably, the parents directly link the eCraft2Learn learning intervention with the development of social skills. Although in general they do not elaborate on how the 'social skills' are defined and perceived, one statement appears to be slightly more enlightening, by closely linking the reference to "social skills" with improved ability to interact effectively with others and to share ideas among one another. Although the social skills are not directly reflected in the keywords of our claims, the documentation is made as they are closely connected to the 21st century skills framework and more specifically to life and career skills.

> *"I would like to mention that what was going on in the eCraft2Learn pilots the past months was very important. My daughter was looking forward to it. She was not very extroverted and I was surprised when she joyfully announced to us that she would participate in the Athens Science Festival with her team. Now that the workshop is over, she still meets up with her team members. They met up several times during the summer here at our house but also outside. She made good friends and she definitely became more social. I noticed that they [meaning: the students that meet up] are discussing and putting together many different ideas for new projects in robotics [...]"* (Mother of participating student G, GR)

The following Table presents the 21st century skills that were fostered based on parents' perspectives as well as the frequency of their appearance.

Table 3. The 21st century skills reflected in parents' statements.

21st century skill	Relation to claims	Frequency of appearance in the 7 statements
Collaboration/teamwork	direct connection to the 4th claim	6 out of 7
Problem solving	direct connection to the 3rd claim	3 out of 7
Critical thinking	direct connection to the 2nd claim	1 out of 7
Creativity	direct connection to the 1st claim	3 out of 7
Social skills	indirect connection to the 5 claim	4 out of 7

Technical skills	indirect connection to the 5 claims	6 out of 7

We are well aware of the fact that the number of received statements/comments by the parents is small, and as such, they cannot be readily generalised beyond the context of this study. The purpose, however, is not to form generalizations but to illustrate the characteristics that support the validation of our claims about the potential of the eCraft2Learn ecosystem to foster 21st century skills. The transferability of the findings is feasible, nevertheless, as they might be applicable in similar contexts and settings. Parents' perspectives on the eCraft2Learn initiative contribute to the validation of the aforementioned claim when seen in conjunction with the other findings gained through interviews, questionnaires, diaries and observations (see sections 4.1, 4.3 and 4.4).

5 Conclusion and Recommendations

This report aimed at validating the five claims regarding the educational value of the eCraft2Learn ecosystem. First, the focus was put on sources of evidence related to whether the eCraft2Learn ecosystem can foster creativity, critical thinking, problem solving and collaboration/team working skills to students. Second, the focus was placed on whether the technical environment/core of the eCraft2Learn ecosystem can support the craft and project-based learning pedagogy (see D3.3). The validation of the claims was based on the impact measurement analysis conducted for the needs of D5.4 as well as on additional analyses (mainly qualitative) of the data retrieved from students' diaries, teachers' diaries, students and teachers' interviews, students' final questionnaire and observation forms. Parents' comments and statements as well as emerging reports by the teachers (in a narrative form) regarding changes in students' behaviour and attitude were also analysed contributing further to the validation of the five claims.

There is no doubt that several cognitive skills are gained as the students imagine, plan, create, program, tinker, design, share, and especially when they are encouraged to do and explore things together. However, the skills that are fostered through the eCraft2Learn ecosystem are not limited to cognitive and STEAM skills. Though these benefits may accrue along the way, the most salient benefits of the eCraft2Learn ecosystem for the students validated in this study have to do with the development of team working skills, creativity, problem-solving and critical thinking skills as well as a sense of self and a sense of community that empower them to shape the designed dimension of their world and to think and work together on issues of critical concern.

In the context of the eCraft2Learn methodology, the students can go through multiple processes: from idea generation, to planning, to collaborative hands-on construction, to problem solving, reflection, sharing, re-design and re-construction. All these processes are interwoven in the eCraft2Learn pedagogical model and learning methodology and reflected well in the eCraft2Learn technical environment.

The projects that were developed by the students were interdisciplinary in nature and in line with the philosophy of the “*maker movement*”. The projects may not be “*spectacular*” but have offered students unique opportunities to explore a rich set of robotics tools and technologies, to act as members of a team, to be creative, to tinker their constructions and challenge seeking, to fail and to keep trying, to be involved in problem solving, to communicate and share ideas with classmates but also with people from a wide range of ages and knowledge thanks to their participation in the Athens Science Festival, the Joensuu Science Festival and other public events. Students have highly valued their involvement in the hands-on activities and showed strong sense of ownership of the final artefacts.

Recommendations

As an outcome of this study and our eCraft2Learn experiences, we can formulate the following recommendations on educational issues that have emerged during the pilots. First of all, it is highly suggested to integrate and foster digital hands-on activities in formal as well as in informal learning settings following the eCraft2learn technical and pedagogical methodology which will allow students to learn and create in a tangible way as well as foster their creativity, critical thinking collaboration and problem solving skills.

Novices should be smoothly introduced to the making activities

The iterative nature of the eCraft2Learn learning methodology allowed for reflection and helped students to see that failure is an important part of the learning process. Though trial-and-error efforts are welcome in the constructivist approach, and some frustration is inevitable when we engage learners in open projects, we have found, in good line with other researchers (Blikstein, P. et. al. 2016), that novices coming into the eCraft2Learn ecosystem need a considerable amount of support and facilitation before they can start making their own projects. Learners, especially the novices, should be carefully introduced to the lab activities and not to be exposed to excessive levels of frustration (Blikstein, P. et. al. 2016) in order to avoid disappointment and discouragement. In addition, it seems that the eCraft2Learn learning experiences have impacted positively on students’ self-confidence and self-esteem, sense of self and sense of belonging in a team. Noteworthy, participating teachers mentioned that they observed significant changes in students’ behaviour, attitudes and growth mind-set.

Change of roles takes time…

The eCraft2Learn learning approach requires a change of the role of the teacher (acting as coach) and students (acting increasingly self-driven and self-determined). The eCraft2Learn educational methodology invites teachers to rethink their role and instead of acting as instructors to act rather as facilitators or coaches. Profoundly, this change requires time to happen for both target groups, teachers and students. However, the validation process has shown that the eCraft2Learn pilots provided a great way to open a new perspective for students and teachers. In long-term view students will learn to work independently, self-directed and self-driven.

From easy to start with projects to the free selection of projects by the students

In the beginning of a robotics course, easy to start with projects can be selected with the aim to smoothly familiarize the students with the available tools and the kind of robotic artefacts that can be created. As the sessions are progressing the teachers withdraw scaffolding and reduce the level of support encouraging free choice in project selection. The students are encouraged to ideate and plan their own projects. More precisely, the students are being challenged to generate new ideas for projects that they would like to implement in the next sessions. Students' ideas and plans may be not very clear in the beginning. However, as the sessions are progressing, they bring more specific or thematic ideas into focus. For instance, quite often students express an interest in creating a robotic car or a moving robotic artefact that can be somehow controlled by them. Some of their ideas may be vague while some others more specific. For example, they may refer to robotic vehicles that move and change colours, a solar car, a vehicle with different sensors, cars that move around avoiding obstacles and more. Building upon this interest, the teachers should support the projects while providing students with the freedom to personalise their creations and to give them the form they like.

Support sharing with the community

Moreover, it is recommended for teachers to exploit different ways of sharing and presentations that will support students to gain new skills of collaboration and entrepreneurship. This could be even more expanded through seeking support and communication with experienced community groups that can provide students with valuable tips, advice and inspiration. The need in society to think and work together on issues of critical concern has increased, shifting the emphasis from individual efforts to group work and from independence to community. The eCraft2Learn ecosystem seems to accommodate well this need by providing students with opportunities to work creatively with others, to develop, implement and communicate new ideas to others.

From "*black boxes*" to the "*white box*" paradigm

The eCraft2Learn project supports and highly recommends the transition from pre-programmed, pre-fabricated solutions and silo products, which appear as "black boxes" for learners, towards a "*white box*" paradigm where learners change role from consumers of technology to designers and makers of transparent robotic artefacts. The eCraft2Learn ecosystem invites the learner to see inside the "*black box*", to disassemble black box technologies to see how they work, to tinker with the source code of tools making it smoothly their own.

However, when children implement their projects and build their artefacts, there are instances when some black boxes seem necessary to help them advance their projects beyond a certain level. For instance, while they are building a robotic car, they need to use motors and a specific integrated circuit motor driver (e. g. the L293 chip) for simultaneous, bi-directional control of the motors. In the eCraft2Learn pilots, the wiring diagram of the L293 chip was given ready to use (hence as a black box) since it is quite complex for students but necessary for driving the motors.

In another instance during the pilots, the Artificial Intelligence (AI) block used in the Snap4Arduino to achieve the voice or image recognition was provided as a pre-defined block; the students and the teachers simply copied and pasted the AI block in their code. Hence, the block was offered as a black box since its inner working was hidden from or not relevant for the user. However, this block enables the user to experiment and explore valuable AI ideas and actions like voice or image recognition. In cases like the ones mentioned above, we recommend that students can use generic building blocks (even as "*black boxes*") if they contribute to the construction of a technically robust computer-supported artefact or to computer-supported artefacts with advanced behaviours in any case, the teachers should choose "black boxes" carefully and decide upon their use. They can also invite the students to see inside the "black box" providing the necessary level of support.

Select technologies that offer "*the simplest ways to do the most complex things*"

Further recommendations concern the technologies we put in students' hands. They must be appropriate for their age, knowledge and skills level. We have seen children (and teachers as well) in eCraft2Learn pilots struggling to use electronic boards and sets that come with too many technical functions and services, pins, wires, and small-size components, not all necessary for the learning tasks and in too small dimensions and sizes, may be convenient for skilled professionals or hobbyists but not so much for young learners. We recommend, in line with the relevant literature and the eCraft2Learn experiences that technologies like robotics or electronics boards and kits intended for education should be specifically designed for education, compatible with learners' skills, needs and interests. We recommend technologies that offer "*the simplest ways to do the most complex things*" (Resnick, M. et. al. 2005). Reducing or hiding the unnecessary technical details can improve the user experience and foster new forms of creativity (Resnick, M. et. al. 2005).

The challenge regarding the technical platforms intended for professionals or hobbyists with a high learning potential is how to transform or adapt them before bringing them in the class to make convenient for learners to use in meaningful ways that will serve the learning purposes. We conceive this transformation as an abstraction that removes or keep out of sight the unnecessary technical details and components while highlights the useful parts in ways that make them clear and easy to use for learners. Moreover, preparatory classes and well-designed materials should familiarise learners with basic skills and knowledge in using electronics and boards before exposing them to open projects.

Similar recommendations go to the programming tools. We recommend simple, visual, block-based environments specifically designed for children instead of professional or general-purpose programming languages.

Emphasis on the process instead of the final product

Education is often dominated by the "*product culture*" coming from competitions, exhibitions and science fairs that gives precedence to the final product over the process. In contrast with this culture, we recommend that the emphasis should be put not on the final product but rather on the making process. Students' teams should be allowed to work at their own pace to develop their projects without any pressure to finish with a predefined product. Instead of "*spectacular*" or exotic projects, we call to start with rather simple projects, that will be inviting for novices, relevant for the children involved including those with low technical background or those with poor skills. It is important that in the end the students can proudly claim ownership of their projects. However, arguing for the simplicity of the student's projects does not mean that we recommend "*easy fun*". The projects should have "*low floor*" and "*high ceiling*" (Resnick, M. et. al. 2005) to offer an easy entry for novices while enabling more experienced learners to work on increasingly more advanced projects; noteworthy, the projects may have also "wide walls" to support a wide range of different explorations (Resnick, M. et. al. 2005) and can be easily extended in new situations and contexts or inspire new ideas for more advanced and innovative projects. We have observed in the eCraft2Learn projects learners working with passion to manage some difficult tasks going sometimes beyond their comfort zone. The process we recommend is not without difficulties, and may involve some frustration and failures.

Support "*tinkering*"

Quite often in robotics classes learners are rushed ahead to make a pre-defined robot or to find the unique solution to a pre-defined problem. In contrast with this practice, teachers should make room for free explorations and encourage "*tinkering*" (Resnick, M. et. al. 2013). Tinkering involves an iterative way of exploring different solutions, alternative constructions, "*what if*" experimentations, testing new parameters in a problem and much trial and error that can engage learners in a "*deep conversation*" (Resnick, M. et. al. 2013).

Visibility in the lab

Everything in a lab that wishes to incorporate the making culture must be visible and easily accessible by learners. The qualities of visibility and transparency refer both to the lab environment and to the students' projects. Visual access to the lab environment is beneficial for learners since it provides easy access to the different tools and materials available in the lab. This is important not only for facilitating learners' work in the lab but more importantly because visual access may generate questions, inspire new solutions or spark ideas for new projects (Kafai, Y. et. al. 2014).

Finally, the validated paradigm reported in this deliverable can inform and inspire new curricula and OERs that will be created in the future with the aim to make STEAM education meaningful and appealing for students and develop real world skills instead of trivial knowledge. The eCraft2Learn project paradigm recommends that the 21st century learning ecosystems should be designed in a way that can actively engage students in hands-on activities that promote creativity, critical thinking, teamwork, and problem solving skills.

Hopefully, this educational paradigm shift will help educators and students appreciate the potential of digital fabrication, DIY philosophy and making culture, navigate the future of maker movement in education and provide insight into how hands-on learning experiences with digital fabrication, DIY electronics and robotics can develop the 21st century skills.

In practical terms, the validated eCraft2Learn paradigm can promote and support future training courses for teachers and learning activities for students to disseminate further the benefits of the maker movement in education for all. Our plans include also the establishment of European summer schools in Athens that will receive teachers/student-teachers and high secondary school students from other European countries. We envision also the establishment of a Master course at University level specialized in educational robotics to offer post-graduate studies for those of the teachers who will wish to deepen more in the introduction of the maker movement in education at academic level after their participation in the summer school. Both summer schools and master courses can put in further practice and exploration the educational paradigm suggested by the eCraft2Learn project to promote the making culture into school and informal education.

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7 Appendix 1 - Data Used For the Analysis

Teachers' diaries

Table 4. Per Pilot Site - Ideation/ Imagine. Did the students go through this stage today?

Pilot Sites	No	Yes but to a limited extent	Yes	Total
Informal Greek	2	12	33	47
Formal Greek	0	1	48	49
Informal Finnish	0	3	12	15
Formal Finnish	0	16	56	72

Table 5. Per Pilot Site - Planning. Did the students go through this stage today?

Pilot Sites	No	Yes but to a limited extent	Yes	Total
Informal Greek	8	18	21	47
Formal Greek	0	1	48	49
Informal Finnish	0	3	13	16
Formal Finnish	0	19	70	89

Table 6. Per Pilot Site - Create. Did the students go through this stage today?

Pilot Site	No	Yes but to a limited extent	Yes	Total
Informal Greek	3	11	33	47
Formal Greek	0	27	22	49
Informal Finnish	0	5	12	17
Formal Finnish	0	18	126	144

Table 7. Per Pilot Site - Program. Did the students go through this stage today?

Pilot Site	No	Yes but to a limited extent	Yes	Total
Informal Greek	9	20	18	47
Formal Greek	10	12	27	49
Informal Finnish	0	2	15	17
Formal Finnish	0	13	94	107

Table 8. Per Pilot Site - Share. Did the students go through this stage today?

Pilot Site	No	Yes but to a limited extent	Yes	Total
Informal Greek	12	15	20	47
Formal Greek	32	13	4	49
Informal Finnish	0	6	6	12
Formal Finnish	0	19	23	42

Table 9. Per Pilot Site - How was the collaboration among the team members?

Pilot Site	fair	good	No collaboration	poor	very good
Informal Greek	6	9	3	2	17
Formal Greek	1	26	14	8	49
Informal Finnish	0	4	4	0	8
Formal Finnish	0	0	8	3	11

Table 10. Per Pilot Site - To what extent are you satisfied with the progress made by your team today?

Pilot Site	Not at all	Very little	Somewhat	To a great extent	Total
Informal Greek	0	1	9	27	37
Formal Greek	8	15	48	34	105
Informal Finnish	0	0	3	6	9
Formal Finnish	0	0	5	11	16

Table 11. Per Pilot Site - To what extent are you satisfied with the creativity demonstrated by your team today?

Pilot Site	Not at all	Very little	Somewhat	To a great extent	Total
Informal Greek	1	1	17	27	46
Formal Greek	1	8	26	14	49
Informal Finnish	0	0	4	4	8
Formal Finnish	0	3	0	8	11

Table 12. Per Pilot Site - Where do you place your role in the workshop based on today's experience?

Scale	1	2	3	4	5	Total
Informal Greek	1	2	16	22	5	46
Formal Greek	0	4	6	32	7	49
Informal Finnish	0	0	1	1	2	4
Formal Finnish	0	0	0	2	7	9

Observation Forms

Table 13. Per Pilot Site - IDEATION

	1st round	2nd round	Total	Percentage to Pilots' SubTotal
Greek Informal pilot site (Technopolis)				
IDEATION				
Yes	31	7	38	54,29%
Yes, but to a limited extent	14	5	19	27,14%
No	10	3	13	18,57%
SubTotal	55	15	70	
Greek Formal pilot site (1st EPAL of Korydallos)				
IDEATION				
Yes	48	7	55	91,67%
Yes, but to a limited extent	4	1	5	8,33%
No	0	0	0	0,00%
SubTotal	52	8	60	
Finnish Informal pilot site (Makerspace informal Joensuu)				
IDEATION				
Yes	7	13	20	60,61%
Yes, but to a limited extent	10	1	11	33,33%
No	1	1	2	6,06%
SubTotal	18	15	33	
Finnish Formal pilot site (Pataluoto 8C/8D)				
IDEATION				
Yes	58	34	92	57,86%
Yes, but to a limited extent	28	17	45	28,30%
No	16	6	22	13,84%
SubTotal	102	57	159	

Table 14. Per Pilot Site - PLANNING

	1st round	2nd round	Total	Percentage to Pilots' SubTotal
Greek Informal pilot site (Technopolis)				
PLANNING				
Yes	28	7	35	48,61%
Yes, but to a limited extent	19	6	25	34,72%
No	8	4	12	16,67%
SubTotal	55	17	72	
Greek Formal pilot site (1st EPAL of Korydallos)				
PLANNING				
Yes	46	6	52	88,14%
Yes, but to a limited extent	5	2	7	11,86%
No	0	0	0	0,00%
SubTotal	51	8	59	
Finnish Informal pilot site (Makerspace informal Joensuu)				
PLANNING				
Yes	10	12	22	66,67%
Yes, but to a limited extent	8	3	11	33,33%
No	0	0	0	0,00%
SubTotal	18	15	33	
Finnish Formal pilot site (Pataluoto 8C/8D)				
PLANNING				
Yes	44	34	78	49,37%
Yes, but to a limited extent	15	16	31	19,62%
No	42	7	49	31,01%
SubTotal	101	57	158	

Table 15. Per Pilot Site - CREATION

	1st round	2nd round	Total	Percentage to Pilots' SubTotal
Greek Informal pilot site (Technopolis)				
CREATION				
Yes	49	11	60	81,08%
Yes, but to a limited extent	2	5	7	9,46%
No	4	3	7	9,46%
SubTotal	55	19	74	
Greek Formal pilot site (1st EPAL of Korydallos)				
CREATION				
Yes	23	4	27	45,00%
Yes, but to a limited extent	28	4	32	53,33%
No	1	0	1	1,67%
SubTotal	52	8	60	
Finnish Informal pilot site (Makerspace informal Joensuu)				
CREATION				
Yes	11	14	25	75,76%
Yes, but to a limited extent	4	0	4	12,12%
No	3	1	4	12,12%
SubTotal	18	15	33	
Finnish Formal pilot site (Pataluoto 8C/8D)				
CREATION				
Yes	72	48	120	75,95%
Yes, but to a limited extent	16	4	20	12,66%
No	13	5	18	11,39%
SubTotal	101	57	158	

Table 16. Per Pilot Site - PROGRAM

	1st round	2nd round	Total	Percentage to Pilots' SubTotal
Greek Informal pilot site (Technopolis)				
PROGRAM				
Yes	50	8	58	80,56%
Yes, but to a limited extent	2	3	5	6,94%
No	0	9	9	12,50%
SubTotal	52	20	72	
Greek Formal pilot site (1st EPAL of Korydallos)				
PROGRAM				
Yes	23	5	28	46,67%
Yes, but to a limited extent	15	3	18	30,00%
No	14	0	14	23,33%
SubTotal	52	8	60	
Finnish Informal pilot site (Makerspace informal Joensuu)				
PROGRAM				
Yes	6	14	20	60,61%
Yes, but to a limited extent	2	0	2	6,06%
No	10	1	11	33,33%
SubTotal	18	15	33	
Finnish Formal pilot site (Pataluoto 8C/8D)				
PROGRAM				
Yes	50	40	90	56,96%
Yes, but to a limited extent	5	3	8	5,06%
No	46	14	60	37,97%
SubTotal	101	57	158	

Table 17. Per Pilot Site - SHARE

	1st round	2nd round	Total	Percentage to Pilots' SubTotal
Greek Informal pilot site (Technopolis)				
SHARE				
Yes	31	3	34	53,97%
Yes, but to a limited extent	10	2	12	19,05%
No	5	12	17	26,98%
SubTotal	46	17	63	
Greek Formal pilot site (1st EPAL of Korydallos)				
SHARE				
Yes	3	0	3	5,56%
Yes, but to a limited extent	4	2	6	11,11%
No	43	2	45	83,33%
SubTotal	50	4	54	
Finnish Informal pilot site (Makerspace informal Joensuu)				
SHARE				
Yes	0	3	3	9,09%
Yes, but to a limited extent	1	1	2	6,06%
No	17	11	28	84,85%
SubTotal	18	15	33	
Finnish Formal pilot site (Pataluoto 8C/8D)				
SHARE				
Yes	24	6	30	18,07%
Yes, but to a limited extent	10	9	19	11,45%
No	71	46	117	70,48%
SubTotal	105	61	166	

Table 18. Per Pilot Site - Project/Artefact construction

	1st round	2nd round	Total	Percentage to Pilots' SubTotal
Greek Informal pilot site (Technopolis)				
Project/Artefact construction				
Yes	42	1	43	57,33%
Yes, but to a limited extent	13	13	26	34,67%
No	0	6	6	8,00%
SubTotal	55	20	75	
Greek Formal pilot site (1st EPAL of Korydallos)				
Project/Artefact construction				
Yes	9	2	11	18,33%
Yes, but to a limited extent	46	0	46	76,67%
No	3	0	3	5,00%
SubTotal	58	2	60	
Finnish Informal pilot site (Makerspace informal Joensuu)				
Project/Artefact construction				
Yes	15	13	28	84,85%
Yes, but to a limited extent	0	2	2	6,06%
No	3	0	3	9,09%
SubTotal	18	15	33	
Finnish Formal pilot site (Pataluoto 8C/8D)				
Project/Artefact construction				
Yes	76	50	126	79,75%
Yes, but to a limited extent	16	4	20	12,66%
No	8	4	12	7,59%
SubTotal	100	58	158	

Final Student Questionnaires

Table 19. Per Country - Question - During the workshop I was able to be innovative

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	3	0	10	65	78
Finnish	2	3	34	37	76

Table 20. Per Pilot Type - Question - During the workshop I was able to be innovative

Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	0	13	48	61
Formal	5	3	31	54	93

Table 21. Per Country - Question - During the workshop I was able to be creative

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	1	0	16	61	78
Finnish	0	3	14	59	76

Table 22. Per Pilot Type - Question - During the workshop I was able to be creative

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	0	11	50	61
Formal	1	3	19	70	93

Table 23. Per Country - Question - During the workshop I was able to test and try out

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	1	1	13	63	78
Finnish	0	2	13	61	76

Table 24. Per Pilot Type - Question - During the workshop I was able to test and try out

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	0	9	52	61
Formal	1	3	17	72	93

Table 25. Per Country - Question - During the workshop I was able to do the things the way I preferred

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	3	1	26	48	78
Finnish	0	3	28	45	76

Table 26. Per Pilot Type - Question - During the workshop I was able to do the things the way I preferred

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	0	20	41	61
Formal	3	4	34	52	93

Table 27. Per Country - Question - During the workshop I was able to plan and coordinate with others

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	2	2	10	64	78
Finnish	0	3	11	62	76

Table 28. Per Pilot Type - Question - During the workshop I was able to plan and coordinate with others

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	0	4	57	61
Formal	2	5	17	69	93

Table 29. Per Country - Question - I feel more comfortable than before to program

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	2	2	18	56	78
Finnish	0	6	39	31	76

Table 30. Per Pilot Type - Question - I feel more comfortable than before to program

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	2	19	40	61
Formal	2	6	38	47	93

Table 31. Per Country - Question - I feel more comfortable than before to make and craft things

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	4	3	19	52	78
Finnish	0	5	32	39	76

Table 32. Per Pilot Type - Question - I feel more comfortable than before to make and craft things

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	0	19	42	61
Formal	4	8	32	49	93

Table 33. Per Country - Question - I feel more comfortable than before to work with electronics

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	3	2	15	58	78
Finnish	0	8	29	39	76

Table 34. Per Pilot Type - Question - I feel more comfortable than before to work with electronics

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	1	11	49	61
Formal	3	9	33	48	93

Table 35. Per Country - Question - I feel more comfortable than before to tackle problems

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	2	4	18	54	78
Finnish	0	10	40	26	76

Table 36. Per Pilot Type - Question - I feel more comfortable than before to tackle problems

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	1	17	43	61
Formal	2	13	41	37	93

Table 37. Per Country - Question - I feel more comfortable than before to find solutions for issues that we faced

Countries	No answer	Not at all	A bit	Yes	Total Sum
Greek	2	1	18	57	78
Finnish	0	8	36	32	76

Table 38. Per Pilot Type - Question - I feel more comfortable than before to find solutions for issues that we faced

Per Pilot Type	No answer	Not at all	A bit	Yes	Total Sum
Informal	0	3	15	43	61
Formal	2	6	39	46	93

Students' Diaries

Table 39. Collaboration Per Country Pilot Sites

The collaboration among the team members was today	Greek Pilot Sites	Finnish Pilot Sites
Very Poor	6	0
Poor	4	2
fair	31	1
good	93	13
very good	217	42
Sum	351	58

Table 40. Collaboration Per Type Pilot Sites

The collaboration among the team members was today	Informal Pilot Sites	Formal Pilot Sites
Very Poor	1	5
Poor	1	5
fair	16	16
good	45	61
very good	177	82
Sum	240	169

8 Appendix 2 Self-Report Cases

The template with the four questions given to teachers (post pilot completion) in order to self-report cases where significant changes in students' behaviours and attitudes had been observed. The template was for optional use.

Teachers report

Please do not mention students' real names

The questions are here to help you write your report in a narrative form

Describe briefly student's profile before his/her engagement in the eCraft2Learn workshops and activities (i.e. age, interests, school performance, behaviour, attributes and more)

Did you notice any change in student's behaviour and attitude after student's engagement in the eCraft2Learn workshop and activities? Are these changes reflected to the profile that was described above?

When did you notice these changes or the first signs?

Are these changes associated with the eCraft2Learn initiative? If yes how?