eCraft2Learn

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

Deliverable D2.2

Future Use Scenarios and Roadmap

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E-Mail:	office@ecraft2learn.eu

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University of Eastern Finland, Finland, (UEF), Coordinator

Edumotiva, Greece (EDUMOTIVA)

Mälardalen University of Sweden, Sweden (MDH)

Zentrum für Soziale Innovation, Austria, (ZSI)

The University of Oxford, United Kingdom, (UOXF)

SYNYO GmbH, Austria, (SYNYO)

University of Padua, Italy, (UNIPD)

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Authors: **Stela Shiroka,** SYNYO

Contributors: **Bernhard Jäger**, SYNYO

Margit Hofer, ZSI

Christian Voigt, ZSI

Reviewers: **Kenneth Kahn,** UOXF

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TABLE OF CONTENT

TABLE OF TABLES

EXECUTIVE SUMMARY

Building on the knowledge generated and outcomes of Deliverable 2.1 'Enabling maker innovations in education: Barriers and drivers', this deliverable uses future studies methods to build possible future outcomes related to innovation conditions in education. Future scenarios were built on the basis of the 25 qualitative interviews conducted as part of deliverable 2.1, a workshop with members of the eCraft2Learn consortium and continuous feedback from the teachers involved in the eCraft2Learn pilot activities.

The report presents two types of scenarios both of which seek to investigate the role of educational technologies, governance, resources and teacher skills in enabling innovation in education. The first set is based on three of the six OECD *Schooling for Tomorrow* scenarios describing the general roles of our categories of interest in each scenario. The second set of future scenarios narrates real-life stories that deal with the identified opportunities and challenges of open innovation in education.

Both scenario types serve as the ground for creating a roadmap to an innovation-minted future by building strategies and recommendations for all involved stakeholders. As such, the roadmap addresses teachers, school principals, national level governance, European level governance and educational technology providers. Since the eCraft2Learn project is also involved with building technical tools for innovative teaching in STEAM subjects, the recommendations entailed in this report also directly address the designs in Work Package 4 (the development of the educational extension software and the Unified User Interface).

1 INTRODUCTION

This report is the second contribution of Work Package 2 'Managing Open Innovations and the Future Scenarios', providing the second main part of the work package, 'the future scenarios'. Deliverable 2.1 presented the concept of open innovation in education, the types of innovation, and some existing methods for innovation management. Its second part, concerned with the analysis of the current situation in schools, presented findings from 25 qualitative interviews with teachers and business representatives conducted in 9 European countries between June and August 2017.

One of the foci of the interviews with teachers was their knowledge and conceptualisation of innovation in general, as well as the barriers and enablers of innovation in their school environments. 'Based on this early view of barriers and enablers of open innovation in education', this report seeks to look into the future and observe possible scenarios which provide an interplay of existing barriers and enablers. Future studies are a strategic method used for developing strategies and policies and can lead to desired outcomes[1]. The OECD has employed the method of future thinking for developing a set of scenarios that may be observed in the future of education. The future scenarios of relevance to the eCraft2Learn project are related to the management of open innovation in education or in other words, the leverage of the barriers and activation of enablers. Based on early assumptions, and also confirmed by the interviews' results, the four variables at play in preventing or enabling innovation in education are 1) education technologies (the design of technologies, strategies pursued by industrial providers and the overall market conditions); 2) governance (at school, regional, national, and transnational level); 3) resources (financial resources, training offers and time); and 4) teachers skills.

The roles and chances that each of these variables might bring in or play in the future for activating an environment which supports open innovation - or on the other hand continuing with the traditional status-quo that impedes innovative methods and approaches in education, - serves as the ground for the development of the concrete recommendations to each of the stakeholder groups.

Seeking to address the aforementioned aims, this report is structured in three following parts: Chapter 2 presents a summary of innovation barriers and enablers based on the findings of Deliverable 2.1 and the state of art of research and analysis on innovation conditions in education; Chapter 3 presents the future scenarios developed in two different formats; Chapter 4 presents the way forward to leveraging existing barriers and finding alternative means for major hindrances to innovation in education.

[1] See. (OECD 2004; Helsinki 2016; Iversen, Miller et al. 2006)

2 INNOVATION CONDITIONS IN EDUCATION

The critical focus of the 25 interviews with teachers from 9 European countries - including very differentiating regions and levels of development - was their knowledge and assessment of innovation barriers and enablers in their school environment. Questions were structured around the skills and knowledge to promote innovation, knowledge of the market of educational technologies, restrictions in terms of costs and regulations, as well as techniques and activities that serve as innovation enablers and innovation management. Table 1 presents the findings from the interviews on barriers grouping them to corresponding enablers that can be considered as counter-measures. The third column of the table assesses an impact that the activation of the enablers could have in the education system.

Table 1: Barriers and Enablers of Innovation in Education

Innovation Barriers	Innovation Enablers	Impacts
Governance Lack of a supportive collaborative culture Management incentives not structured Lack of systemic innovation process Short-term focus Lack of a supportive and motivating culture / environment Belief that innovation is risky Lack of understanding of market conditions	**Improved Innovation Management Techniques – (Strategic Planning of Open Innovation)** Platforms for sharing information Special interest groups for knowledge exchange Interdepartmental work Specific communication tools (Intranet/Groupware etc.) Platforms for networking Project/product champions Platforms for sharing success stories Collection of information on innovation Market competence/intelligence	Increased market intelligence Networking Participatory designs
Regulations (Curricula) Lack of time Standardised tests	**New curricula to include project and craft-based learning**	Elimination of the time problem Increased incentives
Resources Lack of funding	**Alternative means** Finding external donors Ready to use technologies and open designs	Open design technologies enable wider usage and eliminates the lack of funds for the purchase or expensive software/hardware

Teacher skills Lack of familiarity with the concept Lack of technical skills	**New hiring methods for skilled teachers** **Development options for teachers** Ø Professional development Ø Technical competence Ø Organizational competence	Adequate training opportunities for teachers enhance their overall digital skills and increase then application of making technologies as part of learning

Additional literature addressing open innovation practices and techniques in general seems to be abundant, research related to barriers and enablers of innovation in education however not quite so. A major contribution and knowledge provider in the field is the OECD (Organisation for Economic Co-operation and Development)'s Centre for Educational Research and Innovation (CERI). CERI's research projects are concerned with education and learning at all ages, having a particular concern with emerging trends and issues, reflecting on the futures of schools and universities and setting an agenda for the future[2].

One of CERI's research projects Innovative Learning Environments determines some key factors on which to focus in growing and sustaining innovative learning environments (innovation enablers): evaluation and evidence, technology, organisational change and system building and transformation[3]. Additional projects concerned with innovation in schools include *Strategic education governance*, *Governing complex education systems*, *Trends Shaping education* and *21st Century children*. Most of the knowledge generated and presented by these projects is concerned with global trends like disruptive digital technologies and other socio-economic trends like migration and mobility, economic inequality, social structures and networks, etc.

A very detailed analysis of variables impacting the ability of schools to implement innovation was put together by Terry Heick, founder of the Teach Though blog and education specialist dealing among others with project-based learning. According to Heick (2017), the following aspects of the current schooling systems can mostly 'kill' innovation:

1. **Overworked teachers**: Teachers are usually drowned in paperwork, meetings, and accountability tasks leaving them no time for innovation.
2. **Scripted Curricula**: are often provided by national education authorities to keep all teachers 'on the same page' and make tracking results simpler, however making personalised learning and innovation impermeable.
3. **Traditional report cards & progress reporting**: The fundamental relationship between learner, family and content is tied up in the iconic report card, reducing the complex and messy process of learning.

[2] http://www.oecd.org/education/ceri/trends-shaping-education.htm

[3] https://www.oecd-ilibrary.org/education/innovative-learning-environments/creating-and-sustaining-innovative-learning_9789264203488-10-en

4. **(Bad) District/regional programs**: Existing programs provided at the district/regional level are rarely supporting innovation in the classroom.
5. **(Useless) Meetings**: Bringing the teachers together in physical meetings is less productive than using digital and social media platforms to allow teachers more time to relax their minds, read about education leisurely and consequently innovate.
6. **(Bad) Policies**: National policies are the next level attempts to 'bring everyone at the same page'. Policies however "hate innovation" since they are not built for that kind of fast-moving thinking and put teachers at odds with other educators and personnel who dutifully follow said policies, making these kinds of educators seem like 'non-team players'.
7. **School and community climate**: Out of fear of breaking the system through disruption, compliance with "research-based" strategies and "district expectation" and policy is valued above all else. Here, innovation is rare—usually the result of a bright, charismatic teacher or hard-working administrator that realizes that somehow, no matter the cost, something has to change.
8. **Innovation Experts in Schools**: Experts in education are a boon to innovation. Thought leadership, expertise in niche areas, and general rallying of the troops through conferences, social media, and blogging is great. The best way these experts affect innovation is through using a kind of cognitive apprenticeship or coaching model to help guide educators through a thinking process that yields the innovations that have makes them successful.
9. **Teacher Turnover**: constantly replacing teachers is a recipe for not only wasted resources, but stagnant thinking conditioned by systems, tradition, policies, and protocol. Innovation itself requires conditions to get off the ground—clout, trust, organization, communication, and so on.
10. **Busy Parents**: Most parents are accustomed to one way of being educated. New learning forms, confuse busy parents, making it difficult for them to support it and worse a harder sell with 'fringe' students for whom current formal learning models barely work.

Each of these aspects of education are variables, the interplay of which determines the future scenarios of schooling. The following section presents possible outcomes of the interplay of the variables with one-another.

3 FUTURE SCENARIOS

To understand how existing barriers and enablers could shape the future and the role of policy- and decision-makers at all governance levels, teachers and the market in shaping the future to the best outcomes, this section presents two sets of scenarios of possible futures. Future studies and scenarios are a popular method for policy and strategy development. CERI's Schooling of Tomorrow (OECD) project is one of the pioneers of the scenario methodology in education. The eCraft2Learn Future Use scenarios are built on the grounds of three of the so-called OECD scenarios (those concerned with the opportunities of schools to employ innovative teaching approaches), describing how the roles of the education technologies, governance, resources and teacher skills would work in a worst case (maintenance of the status-quo), best case (re-schooling) and an alternative, market-imposed case (de-schooling). Following the investigation of the roles of our categories of interest, four narrative scenarios tackling each of the four aspects are presented. The eCraft2Learn future use scenarios are placed in a near future, rather than addressing very futurist trends and outcomes. Since the schooling systems differ widely across Europe, existing practices and approaches to innovation in one system could be considered future goals for more traditional systems. Since the vicinity to the 'future' is thus different for different European countries - not to speak of the global level - the eCraft2Learn scenarios consider the present as a typical traditional school system and describe the future in some of already existing or emerging best-practice examples.

3.1. WHY AND HOW TO USE SCENARIOS

Future scenarios are defined as a "description of a possible future situation, including the path of development leading to that situation". Scenario methods are used to construct different future models that inform stakeholders for present actions. They are thus often used to draw attention to specific issues to policy makers and related stakeholder, to inform the design on technologies (scenario-based design). Future (use) scenarios can be built through quantitative or qualitative methods. Quantitative methods are used for predictive analysis and only capture a narrow aspect without showing the whole complexity of issue being analysed. Qualitative scenarios are based on qualitative methods such as interviews and they have narrative format, including lots of information in a complex manner. Qualitative are more apt in capturing "systems shift, surprises, institutional or cultural changes, etc." Swart et al. (2004) explain: "Narrative offers texture, richness and insight, while quantitative analysis offers structure, discipline and rigor".

A second way to differentiate scenarios is to distinguish between descriptive (or exploratory) and normative methods. Descriptive scenarios picture possible developments in the future based on what we know about the current or past conditions and trends. Normative scenarios, also known as backward (casting) scenarios, are based on the subjective value sets of the scenario creators. They start from plausible, desirable outcomes rather than from current or past trends. By outlining different possible

scenarios in a narrative form, they highlight the desirability of the different pathways a current situation can take. Conversely, undesired outcomes can be modelled in order to analyse how to avoid them. These value sets can be based on the authors' views and/or of stakeholder groups that were consulted in the scenario building process in case of participatory methods. They can also be made explicit by stating clearly what goals the authors and stakeholder groups pursue in their work of creating the scenarios.

The eCraft2Learn future scenarios seek to capture institutional, economic and cultural changes and inform teachers, governance bodies from the school governance to the highest education authorities, industry stakeholders and the internal project designs. As such, qualitative (narrative) scenarios are a more suitable way to reach the expected results.

Qualitative scenario design is more commonly based on interviews and participatory research with stakeholders. The eCraft2Learn scenarios are thus based on qualitative interviews with stakeholders for the education and industry sphere under D2.1, literature review and a workshop with consortium partners. The eCraft2Learn consortium represents a good conglomerate of backgrounds and experiences including educational specialists, technical development specialist as well as representatives from the industry sphere. Such a mix of skills helped bring additional insights - to those from the interviews with teachers and school principals - for the scenario development.

The designed scenarios combine both descriptive and normative forms, the first seeking to describe the potential future for informing the design of technologies in WP4, and the second (normative) seeking to shape the future with recommendations for leveraging innovation barriers in education.

3.2. The Role of Education Technologies, Governance, Resources and Teacher Skills in Selected OECD Schooling scenarios

In 2004, the Schooling of Tomorrow project of OECD's centre for Educational Research and Innovation, designed six possible future scenarios of school systems[4]. The OECD scenarios are pictures of the entire education system, not close-ups of the "school of the future"[5] as such, overlapping with the interest of the eCraft2Learn future use scenarios. Several other initiatives have used these scenarios as bedrocks for analysing other components and aspects of the school systems of the future. A team of educational researchers in Chile for example used the OECD scenarios to analyse the role of ICT in each of the six potential futures[6].

Table 2 shows the six OECD future schooling scenarios grouped in three segments: 1) The "status quo extrapolated" 2) the "re-schooling scenarios" and 3) the "de-schooling" scenarios. To analyse the categories of interest for eCraft2Learn (technologies, governance, resources and teacher skills) we use three of the OECD scenarios that are more involved with the barriers and enables of innovation in

[4] https://www.oecd.org/site/schoolingfortomorrowknowledgebase/

[5] https://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/theschoolingfortomorrowscenarios.htm

[6] https://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/41315689.pdf

schools and the overall education system. The three possible outcomes for the future of innovation in the education systems are grouped in a worst-case scenario (maintenance of the status-quo), a best-case (re-schooling) and a third alternative solution giving more chances to the market extension (de-schooling). All these three cases however are serve as samples for understanding positions of our categories of interest, and in reality, might be more interconnected and complex than they are shown here.

Table 2: Overview of the OECD Future Schooling Scenarios

The "status-quo extrapolated"	The "re-schooling" scenarios	The "de-schooling" scenarios
Scenario 1: Robust bureaucratic school systems scenario	**Scenario 3**: Schools as core social centers	**Scenario 5**: Learner networks and the network society
Scenario 6: Teacher exodus – the meltdown scenario	**Scenario 4**: School as focused learning centers	**Scenario 2**: Extending the market model

3.2.1. Attempting to Maintain the Status Quo – Resistance to Change

Scenario 1.a: "Bureaucratic School Systems Continue"

- Powerful bureaucratic systems, resistance to radical change.
- Schools knitted together into national systems within complex administrative arrangements.
- Political and media commentaries are frequently critical in tone; despite the criticisms, radical change is resisted.
- No major increase in overall funding. The continual extension of schools' duties further stretches resources.
- The use of ICT continues to grow without changing schools' main organisational structures.
- A distinct teacher corps, sometimes with civil service status; strong unions/associations but problematic professional status and rewards.

Education Technologies: Educational technologies in the school setting are very limited or in very slow rise. Modern educational technologies can be observed in informal learning settings - relying on the engagement of parents to make them accessible to students through informal learning at home or extra courses. School labs mostly offer some of the ICT technologies that can already considered 'old enough'. Their use in learning revolves around the concept of "learning about technology" instead of "learning with or through technology". Students take separate ICT (computer) lessons in which they

learn how to use the technologies without linking them to other subjects at the school setting. Students are given projects and assignments which require the use of the computers, internet and additional ICT technologies at home and they present results in a traditional classroom.

Governance: The school curricula are strictly regulated by the state. A national authority controls the educational system. Both students and teachers are regularly assessed through traditional grading systems. Complying to the school curriculum is a performance indicator for teachers. The evaluation system and rankings of schools creates a system in which schools compete for getting the best students and achieving high rankings. Achievements of one school are losses in terms of reputation and student recruiting for the others.

Resources: Financial capacities of schools are very limited. Almost all of the school budget is dedicated to the building maintenance and paying the teachers. Any additional tools and technologies within the school setting happen as extracurricular activities and are financed by external sources (student parents or other donors). The ability to implement technological innovations thus depends on whether the school is located in a wealthy area, either being a private school or a public school of wealthy partners offering extra resources.

Teacher Skills: Teachers have very limited skills of technology. ICT experts to teach teachers on the use of technology are absent. On-the-job training opportunities are not available. When recruiting teachers, technological knowledge is not a key prerequisite. Distinguishably engaged teachers are self-responsible to find alternative training means by external funds (e.g. EU projects and funding schemes). Officers responsible for innovation in developing teachers' skills, understanding market conditions etc. are absent.

3.2.2. RE-SCHOOLING – MAJOR REFORM AND RENEWAL OF SCHOOLS

Scenario 2.b "Schools as Focused Learning Organisations"

- Schools revitalised around a strong knowledge rather than social agenda, in a culture of high quality, experimentation, diversity, and innovation.
- Flourishing new forms of evaluation and competence assessment.
- Large majority of schools justify the label "learning organisations" - strong knowledge management and extensive links to tertiary education.
- Substantial investments, especially in disadvantaged communities, to develop flexible, state-of-the-art facilities. ICT used extensively.
- Equality of opportunity is the norm, and not in conflict with "quality" agenda.
- Highly motivated teachers, favourable working conditions. High levels of R&D, professional development, group activities, networking, and mobility in and out of teaching.

Education Technologies: New open source and cheap educational technologies are developed. Students learn coding, programming and advanced computer skills in school. Instead of "learning to use technology" they use technology to learn in STEM/STEAM and other subjects. eLearning opportunities become more abundant and technologies offer personalized learning to differential needs of students. The design and development of education technologies relies on participatory methods reckoning with the needs of the classroom as a whole and the different sets of skills and preferences of students. Besides the regard towards differential needs, evaluation and support, new technologies also seek to teach social values and skills such as teamwork, collective actions tackling the needs of the communities and achieving global development goals.

Governance: The promotion of innovation in education becomes the primary aim of the higher governance instances. They support the creation of communities of practice between the industry, schools and academia and local education innovation clusters are increasingly created. Curricula are liberalised and teachers/principals are free to choose the best methods to teach their students.

Resources: Governments allocate a lot of resources for public schools and bridge the divides between publicly and privately funded schools and the those in wealthy and less developed areas. The extended funds are dedicated to the purchase and implementation of the latest education technologies, the process of open innovation in general and the development of teachers' skills. Additional resources are allocated in research and development activities to the academia and private sector.

Teacher Skills: The teacher profession is respected and well-paid. To be qualified for the job, teachers must complete high-standard higher education programmes and the evidence high technical skills and cross-subject competencies. Abundant on-the-job training opportunities are available and innovation officials in the school are responsible for the professional development of the teachers and for conveying them knowledge on the market. In the classroom teachers assume the role of coaches helping the students in the discovery of knowledge by tackling their differential needs, rather than being presenters of knowledge for the whole group. Learning experiences in the school are supported by a team of teachers from different disciplines and subject areas instead of just one teacher.

3.2.3. DE-SCHOOLING – WIDESPREAD DISESTABLISHMENT OF THE SCHOOL SYSTEMS

Scenario 3.b "Extending the Market Model"

- Market features are significantly extended as governments encourage diversification and withdraw from much of their direct involvement in schooling, pushed by dissatisfaction of "strategic consumers".
- Many new providers in the learning market, with radical reforms of funding structures, incentives and regulation. Diversity of provision but schools survive.
- Key role of choice - of those buying educational services and of those, such as employers, giving market value to different learning routes. Strong focus on cognitive outcomes but also possibly of values.

- Indicators and accreditation arrangements displace direct public monitoring and curriculum regulation.
- Innovation abounds as do painful transitions and inequalities.
- New learning professionals – public, private; full-time, part-time - are created in the learning markets.

Education Technologies: Educational Technologies become very cheap and wide-spread in informal learning settings. Online learning opportunities also boom, giving rise to home-schooling and shifting the focus of learning from the school the market offerings.

Governance: School systems remain resistant to change, following traditional practices, which makes them less and less popular. While there is very little money spent on the education system, the market conditions for the development and establishment of private providers are created and supported. Inequality between different areas rises due to the differential abilities to acquire market offerings.

Resources: Resources dedicated to schools in certain countries and areas remain the same due to overall economic issues. Schools continue having very little resources on their own. Everything relies on parents' contributions and engagement.

Teacher Skills: The school teacher profession becomes less and less popular. Instead new positions in informal learning are created. Informal learning institutions are created where coaches and trainers are responsible for teaching and training technological skills. New generation education specialists offer their expertise via courses and programmes in the online learning market.

3.3. THE ECRAFT2LEARN IMPLEMENTATION SCENARIOS

This section puts the four categories observed above in real life situations by tackling the issues analysed through the OECD scenarios. The following four scenarios describe the challenges and opportunities to implement the eCraft2Learn setting in different contexts in the future. This serves as the ground knowledge for the development of recommendations to stakeholders and creating the roadmap to the future.

Scenario 1 (Governance)

School A in Finland has two innovation officers. Both of them, Annika and Elias received Master Degrees and adequate training in innovation management in education. They are well connected to the industry and academia and continuously attend national and international events to network with stakeholders and keep up-to-date with innovation opportunities. Local knowledge transfer events and cooperation are facilitated by the Education Innovation Cluster in Joensuu. The cluster includes representatives from the academia, the industry and the educational sector. Creating this circle of

exchange lets each of the stakeholder groups share their experiences and contribute to the uptake of knowledge, development of designs that meet the needs of the field and rapid implementation of innovative technologies and approaches. Schools in Finland have abundant financial resources available to implement innovative technologies and approaches to learning. Besides that, the state policies give schools a lot of room for deciding on what to teach and how to teach it. In other words, the curricula and the pedagogical models are mostly decided by the teachers, principals and the innovation officers.

In the annual knowledge transfer event of their cluster - which brings together all involved stakeholders - Annika and Elias learn about the eCraft2Learn project which developed a new learning methodology and requires the implementation of a technical setting to teach STEAM subjects. The five-stages pedagogical model fits very well to the ideology of the school which put a great importance on teamwork, creativity, co-creation and having fun throughout the learning process. As the school has kept an eye on continuously integrating new technologies, some of the items of the eCraft2Learn technical setting, like a 3D printer, are already present in their school.

Annika and Elias gathered enough materials on the methodology created by eCraft2Learn and are excited to propose it to the school principal and the teachers in their weekly meeting.

As expected, both the teachers and the principals find the new idea forward-looking and meeting with their objectives and skills. The info materials that Elias and Annika brought show positive results of the testing phase in other schools. They have close ties to the school that tested the methodology and it seems like teachers of the piloting school are now spreading the word in their connections. It seems like the project results are spreading fast in the education community at their area and acquiring more and more interested teachers and principals.

At the second meeting of the board composed of the STEM teachers, the principal and the innovation officers, once everyone could check the proposal in detail it is consensually agreed to try the eCraft2Learn methodology in teaching STEAM subjects. The next steps Annika and Elias have to think of are implementing the technical setting (which technologies they need to purchase, in what quantity etc.) and finding adequate training for teachers. Though their school continuously trains teachers on advanced use of technologies, in the new methodology they need additional training on what roles they should assume, how that should guide students through the five pedagogical stages etc.

Scenario 2 (Educational Technologies)

In Italy the unemployment rate among the youngest generation is alarming policy makers. Requirements of the 21st century workplace have grown much more rapidly than the skills of the younger generations. High school graduates can no longer compete in the labour market. As a measure against this scenario, the Ministry of Education, Universities and Research is increasingly promoting a structured exchange between the education sphere and academia. Recognising the needs of the market for highly advanced digital skills and competences, policy makers are also in

favour of the implementation education technologies and break-through methods of teaching. In this context, the Ministry is organising several rounds of knowledge transfer events connecting academics with teachers and principals.

At one of these events, Professor Manconi introduces the concept of game-based learning, crafting and programming as activities that could and should be used to teach science, technology, engineering and math. One colleague from his department has worked in the eCraft2Learn project which has built an online platform named as the Unified User Interface. The platform is a supportive tool for a five-step teaching methodology based on craft and project-based learning. To implement craft and project-based learning as part of the teaching process, schools must have a certain technological infrastructure implemented. Educational technologies such as Arduinos, Raspberry Pi-s and 3D printers have become cheap and purchasing them is no longer a problem even for schools in low income areas.

M - '*The tools are there, the state is supporting us to make it happen, it's all in the hands of educators to change mindsets and be more open to innovation'* - says professor Manconi in an informal talk at a networking event with an old colleague that is now the head of the Regional Education Office.

S - '*I know what you mean, but we should not forget this idea of game and project-based learning comes with its implications. You see, first of all schools and teachers have been resistant to innovation for decades and decades. There is the general idea that this is the right way, and it will be right for all time. Making even the slightest changes here requires time and evidence. Like studies, scientific knowledge that this alternative would work, and it would work for better*'.

M - '*I understand what you mean. But such evidence is more than abundant...it just needs to be more visible to the people involved. Well, perhaps also additional studies on the benefits would be helpful, but I still think it's not about the lack of knowledge that make educators resistant to change*'.

S – '*Well, I mention scientific evidence because there are several aspects that are still not convincing to teachers and parents alike. Like games-based learning for example. How can I show to parents their kids are progressing in science and maths after they went home and spoke about playing games in the lesson? You know there is this firm idea that school is a serious thing and it's separate from playing or having fun. And when I say evidence, I mean that we need to show to educators and parents how to evaluate student's progress in these methods. Somehow educational technologies also need to reflect this. I want to be told: here is a new methods or tool or ecosystem you can implement, this is what the students will learn because of this and that reason, this is what the teacher should do to achieve that, and this is how we will measure it at the end. If these issues remain vague, it still sees it difficult to happen*'.

Scenario 3 (Teacher Skills)

In 2023 Greece, the innovation conditions are becoming more and more favourable. What seemed as unreachable until lately, is now becoming more and more accessible to everyone - new educational technology providers are offering cheap tools affordable for all schools. The providers are no longer large companies. National and European funding mechanisms have enabled local providers to develop cheap and open-source technologies that can be accessible also in areas facing economic hardships. In the context of Europe-wide campaigns for innovation in education, the Greek Ministry of Education is supporting the implementation of novel learning technologies in schools and adjusting the school curricula to shift from the traditional century-old teaching. The new national plan involves digital fabrication, programming, 3D modelling, 3D printing etc. as part of the learning process in science, technology, engineering and math. The concept of introducing arts into the more traditional STEM subjects is now widely embraced and applicable.

Teachers of school A in Athens are welcoming this step, they have been waiting for some time now. They have been involved in several projects and initiatives and trainings on how to be an 'innovative teacher' and push innovation in the school setting. One of the projects they have been involved in, the eCraft2Learn project provided them advanced training in using programming, 3D modelling, 3D printing and additional tools. They were able to test the methodology developed by the project and the tools for digital fabrication with their students. Due to the very positive feedback from the students and their own experiences, they remained enthusiasts of the eCraft2Learn craft- and project-based learning approach. However most of the activities after the end of their involvement in the project were carried out informally and with little resources. One of the most engaged teachers, Sophia created a group in social media where students share their creations, ask questions and connect with peers. Although the curriculum could not allow for much free room during the lessons, that subjects were strictly separate from one another, the online group helped keep the experimental spirit alive and guide students to crafting projects at home in their free time. On the other hand, she kept updated with other initiatives at European level such a SCIENTIX, eTwinning, STEM Alliance etc., completed several massive open online courses (MOOCs) training skills for innovative teachers and develop her capacities continuously.

While the new policy process for the teaching programming and advanced digital skills through project-based learning has already started and gained media presence, Sophia's family decides to move to a smaller city in a remote area. In a few weeks Sophia also moves to a new school. To her surprise, the environment in her new workplace is much more different than it seemed in her open and well-connected school in Athens.

The news about the new national policy is mainly frowned upon. Old teachers are feeling insecure about losing their jobs or unable to match the new requirements. They mainly come from a generation that was not raised with technology and making technologies was not part of their education. The local TV is also increasingly problematizing the topic. In one of her first days with her new colleagues, Sophia happens to listen to a conversation at the teachers meeting room:

A - '*How can I explain to the students something I have not understood myself first? It seems to me like a pretext to cut our jobs*.'

B - '*I admit that our generation might lack skills that are relevant for the new era. But then again, young teachers are receiving the exact same education we received decades ago. I don't see it as a generation problem. They need to think of properly teaching the teachers before they want us to teach the students differently*.'

Scenario 4 (Resources)

In country D the overall economic crisis has left the government's abilities to invest in education, research and innovation in stagnation. Schools receive very little money for covering primary needs, so the capacities for the implementation of breath-through innovations are almost zero. Nevertheless, the director of School X Ana, thinks that you can be innovative also with very little resources. Together with one of her old colleagues Martin who is a teacher of Physics and computer science, they implemented a new strategy for employing the project-based learning and making their school more open. Taking that step was risky and required time and energy to convince both teachers and parents. Today however the school is a champion in open schooling and the students rank among the country's best in general performance. Ana believes that operating under an environment marked by very little resources and curricular restrictions can make innovation less likely and slow, but still not impossible. As a champion school they are invited to share their views on creating an open and innovative school environment with little resources.

A – '*We hear a lot that having to stick to the curriculum is a major barrier to implement innovative teaching. Well I could answer this with one of my favourite quotes 'The curriculum tells you "what", not "how", the "how" is the artistry in education'"*[7]. *Being unable to offer the latest technological innovations within our school environment, we decided to open the school doors to local companies and allow students to conduct projects in real working environments. Both me and Martin who pioneered this idea are members of academic circles and have good personal contacts to the industry in the local area and region. We decided to make use of our connections by creating a board of advisors and donors with representatives from businesses. Our students now spend around 6 to 7 seven weeks outside the school working in a real working environment in very hands-on activities in which they develop skills that are hard to be trained in a traditional school environment*'.

M – '*The most important aspect to succeeding in this was making the teachers embrace and long for this approach. We did not want to impose it on them but instead make sure they understand the benefits and self-motivated to make it happen*[8]. *First, we needed to make sure that this will be in line with their requested efforts, and not add to their workload*'.

[7] https://georgecouros.ca/blog/archives/7842
[8] https://www.youtube.com/watch?v=KK37jecWJz8

A – '*Martin is indeed a champion in teacher leadership!*'

M – '*I am a teacher myself and I know that time management is one of the main problems. Many of my colleagues were until lately constrained to do project work as an extracurricular activity and those who had less free time and family commitments were left with the wish but unable to go outside of the classroom. Good school governance can leverage the time problem. It is also in the hands of the governance to create evaluation schemes that guide teachers into the new teaching approaches'*.

I - *How did you deal with developing teachers skills? For example, advanced technical competence*?

A - *It is true that making teachers confident with technology was a major problem since the teacher education programs do not deal with such skills. Most teachers were educated in a time where the newest technologies we can use today were far from being invented. But more and more online training opportunities are being offered. MOOCs for example are a good free education instrument. We also sought to keep an eye on other European workshops and training opportunities. Besides that, most of the technological providers are now offering free training for the staff which is helpful. Language is sometimes a barrier, since not all teachers are proficient English speakers and most trainings are offered in English. But we chose for example, training those teachers that are mostly proficient in English, and they can then train their colleagues in our language*.

4 ROADMAP - THE WAY FORWARD

As pointed out above, the main purpose of the scenario exercises is the development of policies and strategies that lead to desired outcomes in the future. The future scenarios drawn afore indicate that opportunities for innovative and open education systems are possible, however several barriers that hinder innovation are likely to persist (in a near future), especially in specific (and less developed) areas in Europe. The following recommendations, drown from the scenario exercise target stakeholders involved in the education ecosystem with recommendations for leveraging barriers and activating innovation enablers also in very restrictive conditions.

European Union

Support the creation of additional projects and initiatives to train teachers and introduce the concepts of open innovation in education

The EU can undoubtedly be referred as one of the main actors for pushing forward innovation in education with its support to countless research and innovation projects – including the eCraft2Learn project – and cooperation mechanisms for teachers (especially in the STEM/STEAM) projects. The European Schoolnet founded in 1977 as a network of European Ministries of Education to bring together all involved stakeholders in the ecosystem (teachers, researchers, industry partners) – implements a long list of successful EU-funded projects in the field of education that provide free resources, training, strategies and cooperation options for teachers all over Europe. In these frameworks, new projects are suggested to tackle barriers in the promotion of innovation in schools. Though there are already existing projects researching and developing pedagogies, strategies and open source tools – the eCraft2Learn project being one of them – additional awareness raising and training activities, targeting especially more remote and less connected areas in Europe, supporting different local languages are strategically recommended.

Industry

Engage intensively in dialogue with academia and education specialist to create participatory designs

User-cantered designs of educational technologies are a key prerequisite for their wide embrace by teachers and their overall integration in the ecosystem. Strengthening cooperation with the user communities, but also with educational researchers and policy makers involved in the educational ecosystem, should become part of status-quo of future development processes of educational technologies.

Include evaluations in the design of new technologies

One of the major criticisms from the teacher community regarding the implementation of education technologies as part of formal learning is the absence of evaluation schemes in the design of the technologies. The need to assess student progress to learning at the end of the term, makes the work and incentives of the educators more difficult regarding the implementation of the technology (e.g. game-based learning, digital fabrication etc.) in the classroom. The design of technologies should thus be aligned with pedagogical models of implementation in the classroom including evaluations of learning outcomes and progress assessment. Additionally, demonstrations on the uses of technologies in the classroom, and increased research on their impacts in the learning outcomes of students are necessary for shifting the beliefs of the teachers, school governance, and parents, that innovation is risky.

With regards to programming/digital fabrication in the classroom as part of the eCraft2Learn learning ecosystem, the following aspects should be considered:

- The impact of each type of programming/digital fabrication on specific skills, in particular learning contexts
- The elements of the programming/digital fabrication responsible for the impact on specific skills
- Ways to manage students' different learning styles through programming/digital fabrication in the classroom
- The impact of programming/digital fabrication in learning on subject-specific skills
- The role of the teacher to ensure the potential of programming/digital fabrication in the teaching process is fully realised

Development of open source tools

Considering that most of the schools operate under very limited resources – with the trend not likely to change in the near future – and the resources also contribute to deficiencies in developing teacher skills, making use of open source tools and technologies can empower even the schools with very little resources. The use of open sources software was one of the key aspects in mind in the development of the eCraft2Learn Unified User Interface. Additional developments should continue in that framework.

Offer free training sessions (e.g. as online tutorials in multiple languages) for teachers upon purchase of products

Buying technologies can be costly for schools under the current conditions. In the future more and more schools are expected to be able to afford the implementation of new educational technologies, however inequality between education systems throughout Europe might also continue to persist in the near future. In the scenario when one school is able to afford the purchase of new educational technologies, the next costly step would be the training of teachers on their use and proper

implementation in the teaching process. Offering free online or onsite trainings and tutorials for teachers, in addition to the purchase of the technologies by the school, would increase the incentives of the school to purchase new technologies and implement them in the learning methodology. Online courses with an awareness raising character such as MOOCs or webinar series could raise awareness on the impacts and provide guidance on the implementation of new technologies in the classroom.

National authorities

Liberalise curricula, give schools freedom to experiment

State policies and pre-defined curricula that must be implemented by all schools are one of most spoken out barriers to innovation in education. As mentioned previously in this document, unified state curricula do not leave the schools (and in turn the teachers) the freedom to experiment with new teaching methods, integrate new technologies as part of the teaching process and most importantly are based on the wrong perception that 'one size fits all' not allowing opportunities of personalised teaching and learning. It is thus an immediate necessity of national education authorities to include free sections in the pre-defined curriculum that allow teachers to experiment new methods.

At the very best, in certain counties with highly advanced education systems like Finland, teachers and school principals are in charge of choosing the what to teach and on which methods, supporting experiments at grassroots level. Some education systems organise training in change management and innovation for teachers and school managers. This training relies on (generally modest) financial support given to concrete initiatives conceived at 'grassroots' level, which enjoy a degree of freedom in the choice of projects undertaken. The development of initiatives in the area of programming/digital fabrication could be further encouraged.

More freedom to experiment would also be beneficial in the design on the overall system: from the waving of standardised tests to grading systems that measure student qualities more in detail.

Support the creation of Education Innovation Clusters

Education Innovation Clusters (EIC) are local communities of practice that bring together educators, start-ups, policymakers, investors, researchers, and community groups across the usual boundaries that separate them, with the goal to improve the shared understanding of needs and opportunities (Hodas, 2015)[9]. The idea of the clusters has been implemented only recently in the United States through Digital Promise, a non-profit organisation authorised by the state as the National Center for Research in Advanced Information and Digital Technologies. Putting in place and steering such communities at the local level can ensure that knowledge is continuously exchanged through the different types of stakeholders contributing to more user-cantered designs, research-based

[9] http://digitalpromise.org/2015/03/06/designing-a-network-of-education-innovation-cluster

methodologies, increased market intelligence by schools and teachers, etc. New ideas about future research and development needs can also be the outcomes of such structured exchanges.

School Governance

Creating an innovative and open school environment

Opening schools toward increased partnerships with other actors in the community such as the industry, has long been a priority for the EU funding a wide range of projects to develop concepts, recommendations and action plans for open schooling. One of the most recent projects, *Open Schools for Open Societies* created a highly useful roadmap to open schooling directed to school governance and 'innovative teachers'[10]. Providing unique professional development experiences for school staff, connecting stakeholder organisation, policy makers and the community, expanding student's horizons, improving teaching and raising the school's profile, are listed as the five top reasons to invest in the development of an open school agenda. The key aspect mentioned by the roadmap that is highlighted by the lessons on the eCraft2Learn project, is the shift from students as consumers to creators of knowledge. A school in which students are creators instead of consumers, also requires to shift from the role of the teachers are presenters of information to coachers that provide personalised guidance to the differential needs of the students in discovering and creating knowledge. Both these roles are crucial for the proper implementation of the eCraft2Learn learning methodology.

Coaches are the new teachers

Teachers are shifting their roles from mere presenters of information to coaches adapting to individual needs and talents of students Focus is placed on creating learning experiences in the classroom that are supported from a team of teachers (from different disciplines/subject areas) instead of just one teacher. To support this concept teachers, need to be supported technically, with content, and by establishing reliable systems to control and monitor students' participation and engagement in these learning experiences. The concept requires skilled teachers who can fill the role of coaches that recognize the individual needs of their students and foster their talents. This then brought up two issues: the need for updating initial teacher training curricula and the need to re-consider how students' participation is evaluated.

Students design their own content and material

Students in the future will spend a higher proportion of their time with active thinking and design tasks than they have done in the past. As student technical literacy increase and their informal learning

[10] https://www.rri-tools.eu/-/open-schooling-roadmap-a-guide-for-school-leaders-and-innovative-teachers

experiences are more rich, interactive and collaborative practices in schools are expected to assume a more central role in classrooms and educational material design are expected to be decentralised. 3D modelling and printing, DIY tools, online communities of practice, publishing tools are just few of the tools or services that can be used by the students to create resources. The student creators are expected to design their own educational resources reducing education costs associated with production, design and publication of content and material. Such a practice opens new roles for educational advisors or curriculum designers and teachers and bring into focus the aspects of coaching, co-creating, co-learning, consulting and evaluation and/or accreditation of the produced resources.

Making use of free resources

One of the mostly problematised aspects in impeding innovation in the school was the lack of resources. Certain educational technologies are relatively costly and purchasing large quantities that can be satisfy the needs of the whole school is likely to remain a challenge for many schools in Europe in the near future. Most of schools however tend to blame the lack of resources as an obstacle to innovation closing both eyes to the abundance of available funding opportunities and free resources. Sound market intelligence should consider the following opportunities for schools to cope with limited resources:

- On the EU funding level, the **eTwinning** platform offers great opportunities for schools to connect and share experiences towards innovative futures.
- Specific funding schemes such as **Erasmus+** offers funding opportunities in which schools can participate to bring innovative ideas to life while collaborating and connecting with stakeholders.
- Countless projects funded by other EU schemes – including the eCraft2Lean and others mentioned in this document – offer recommendations, training and guidance for teachers and for school principals to push and steer innovation.
- On the market level, an abundance of resources is offered open source while expensive hardware can also be found in cheaper forms by local producers.

For the eCraft2Learn methodology a set of technical tools is required to fully implement the five-stages pedagogy. Yet, even when lacking some of the resources of the overall technical setting, several of the stages can be performed (especially as part of informal learning). Annex 1 shows some of the available variations of resources. A more detailed guideline building on Annex 1 will be developed as part of the dissemination and exploitation activities in WP6.

Teachers

Teacher leadership and opportunities to promote innovation at your school

Besides crucial role of the school governance and the higher ranked authorities in creating and steering and innovative learning environment within the school, the role of the teachers is often highlighted in contributing to innovation. In the US, the term 'teacher leadership' has long been used for teachers who assume additional leadership roles related to innovation and 'opening' of the school. As part of the 25 interviews with teachers and principals, we had the chance to interview a leading teacher who had been active for many years in connecting the school the academia and the industry, leading the team of STEM teachers in conducting project-based learning while coping with the curriculum requirements, engaging parents and external donors in funding required technologies and projects, and keeping up to date with market offerings and exchange opportunities. Teacher leaders are usually teachers with a longer experience than the rest of the team (but still not among the oldest), with less personal commitments and a great passion for their profession, who have earned the respect of the team and can easily promote team work and strategy building.

The role and impact played by teacher leaders in education is receiving increased scrutiny as the discussion on open schooling and innovative schools increases. Most notoriously, the Teacher Leadership Exploratory Consortium which was created to explore the different models of teacher leadership has delineated the variety of formal and informal roles exercised by teacher leaders and also examined the role of teaching expertise and effectiveness in regard to teacher leadership. The Teacher Leader Model Standards[11] offers guidelines for teachers to run leadership in different domains. Another, more recent publication, from the Whole Child Symposium[12], offers outstanding testimonials and recommendations on teacher leadership.

A key prerequisite to becoming a teacher leader is networking, keeping an open mind and keeping up to date with the concept on innovation and emerging trends. The huge potential of social media can satiate all these needs by enabling teachers to network, share information and receive information and in turn innovating in their environment. Being active on social media, creating groups within the team and the school for promoting activities, following related social media campaigns and hashtags, participating in webinars, MOOCs, additional free trainings, becoming part of EU projects and networks (e.g. Scientix community for Science teachers in Europe) etc. are some of the first steps towards becoming teacher leaders.

[11] http://www.nea.org/assets/docs/TeacherLeaderModelStandards2011.pdf
[12] https://www.ascd.org/ASCD/pdf/siteASCD/wholechild/fall2014wcsreport.pdf

5 REFERENCES

Literature:

Swart, R.J., Raskin, P. & Robinson, J. (2004). *The problem of the future: sustainability science and scenario analysis*. In Global Environmental Change, 14 (pp. 137-146). Elsevier.

Websites:

https://www.demoshelsinki.fi/en/2016/02/12/learning-about-the-future-through-scenarios/, last retrieved on 22.04.2018

http://www.oecd.org/innovation/research/36702582.pdf , last retrieved on 22.04.2018

http://www.oecd.org/education/ceri/trends-shaping-education.htm, last retrieved on 22.04.2018

https://www.oecd.org/site/schoolingfortomorrowknowledgebase/, last retrieved on 22.04.2018

https://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/theschoolingfortomorrowscenarios.htm, last retrieved on 22.04.2018

https://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/41315689.pdf , last retrieved on 22.04.2018

https://www.oecd-ilibrary.org/education/innovative-learning-environments/creating-and-sustaining-innovative-learning_9789264203488-10-en, last retrieved on 22.04.2018

https://georgecouros.ca/blog/archives/7842, last retrieved on 22.04.2018

https://www.youtube.com/watch?v=KK37jecWJz8, last retrieved on 22.04.2018

http://digitalpromise.org/2015/03/06/designing-a-network-of-education-innovation-cluster, last retrieved on 22.04.2018

https://www.rri-tools.eu/-/open-schooling-roadmap-a-guide-for-school-leaders-and-innovative-teachers, last retrieved on 22.04.2018

http://www.nea.org/assets/docs/TeacherLeaderModelStandards2011.pdf, last retrieved on 22.04.2018

https://www.ascd.org/ASCD/pdf/siteASCD/wholechild/fall2014wcsreport.pdf, last retrieved on 22.04.2018

ANNEX 1

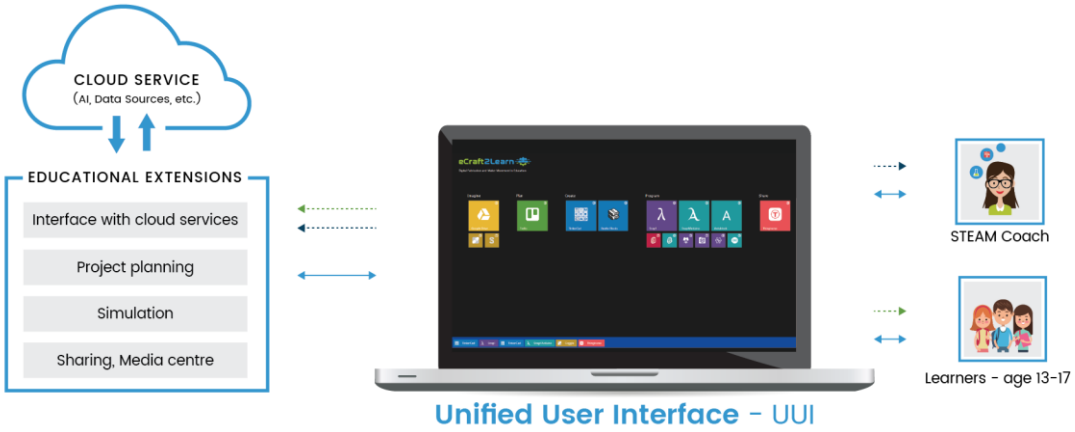

Figure 1. Minimum set of tools required. Representative prototype of the eCraft2Learn User Interface (UI).

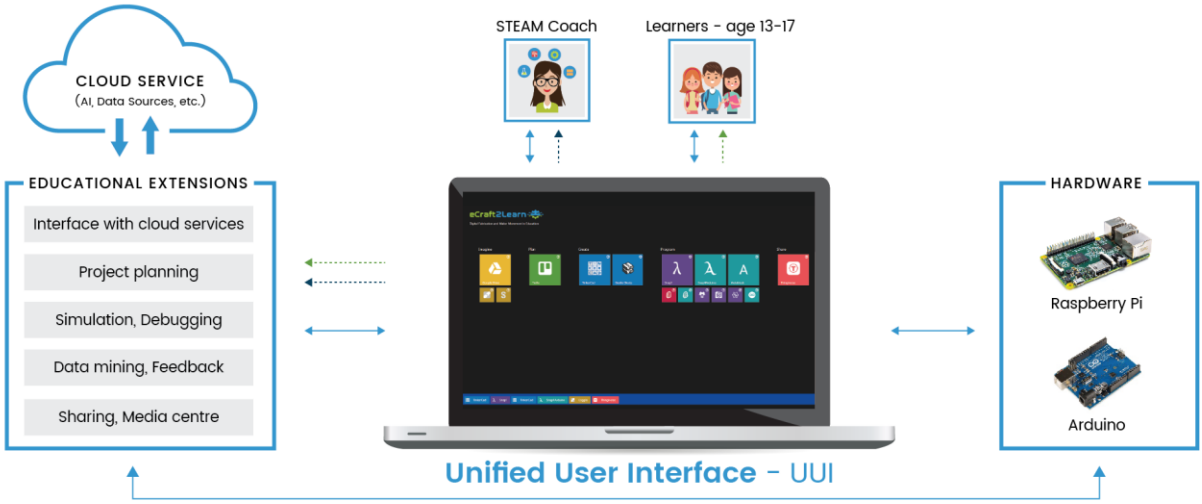

Figure 2. Medium set of tools required. Requires a Hardware extension of the eCraft2Learn ecosystem.

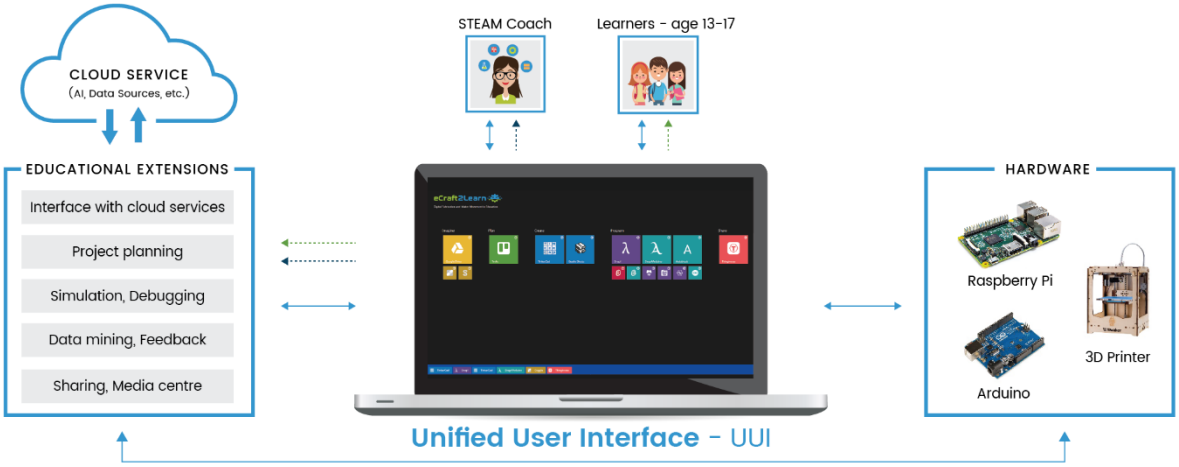

Figure 3. Complete set of tool required. Extension of the 3D Printer will facilitate the creation of the physical components integrated in the creation-programming-sharing workflow.