eCraft2Learn

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

Deliverable D3.1 (ver3)

Development of personalised, craft- and project-based learning

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EXECUTIVE SUMMARY

This report presents the foundations for developing the craft- and project-based learning methodology for flexible and open learning scenarios (WP3). The deliverable presents a description of personalised and adaptive learning scenarios that serve the pedagogical development of craft- and project-based science, technology, engineering, arts, and mathematics (STEAM) education. It also deliberates with D4.1 on the appropriate technologies for use during the eCraft2Learn project in order to integrate the technological core and pedagogical approach of the project. These tasks relate to and support the project business objective 2 (BO2).

The aim of this deliverable is to develop the pedagogical framework for an appropriate craft- and project-based learning methodology to deploy our tech core. The framework is developed within five stages that take into account the features of personalised and adaptive learning within flexible and open learning scenarios: (1) Ideation – Exploring the world; (2) Planning a project; (3) Designing and building a computer-supported artefact; (4) Programming the built computer-supported artefact and (5) Showcasing. These stages are in line with the maker movement and open innovation. In each stage, the awareness of students' learning process as well as regulation and evaluation will be supported in multiple ways. This task also collaborates with WP4 (T4.5) in order to offer appropriate technology to craft- and project-based learning as well as prompts to enhance awareness, evaluation and regulation by utilising, for example, real-time analytics and log data. As the teams proceed step by step, the prompts help them to increase their awareness of their activities so that they can regulate their learning processes. The flexible learning scenarios will also offer personalised learning pathways. Moreover, the educational approach should attract design and art students who are not fans of science and technology. Therefore, we use a combination of different disciplines such as those incorporated within STEAM.

STEAM is used here as an educational approach to learning. In this approach, science, technology, engineering, arts and mathematics are seen as access points for guiding student activities, such as inquiry, dialogue and critical thinking, which enhance learning. This approach assumes to produce students who take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration and work through the creative process[1]. Skills relating to the arts can be developed through product design. Introducing new digital technologies can encourage the incorporation of new materials and disciplines[2].

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1 For further information see http://educationcloset.com/steam/what-is-steam/

2 https://www.createeducation.com/blog/code-create-corelli-college/

1 INTRODUCTION

There is a need for a relevant pedagogical model for personalised learning and teaching within STEAM education. Furthermore, there is a gap between the skills learned in schools and the skills needed in today's work life, for example, in the ICT sector, which hinders economic growth. We assume that digital technology assets can be used to help create an education and innovation ecosystem to overcome these problems. In recent years, digital making technologies have been perceived to enliven technology education, thereby arousing student interest (Nourbakhsh, Hamner, Lauwers, Bernstein, & Disalvo, 2006). Movements such as *digital fabrication* and *making* in education enable us to build a link between the intellectual activities taking place in the classroom and students' experiences in making and building things outside the classroom (Gershenfeld, 2007; Blikstein, 2013).

Following the idea of personalised and adaptive learning paths, making is based on what is personally relevant to an individual, allowing students of all backgrounds to work with their interests and to use arts and craft materials as well as technological tools to develop their own material. This can create more channels for girls to positively identify with computer science and engineering fields (see Intel Report, 2014, p. 7). The eCraft2Learn project will research, design, pilot and validate an ecosystem based on digital fabrication and making technologies for creating computer-supported artefacts. The project aims to reinforce personalised learning and teaching in STEAM education. It also aims to assist in the development of twenty-first century skills that promote inclusion and employability for youth in the EU.

Some examples of twenty-first century skills include skills of collaboration – negotiation and communication – and creativity, critical thinking, problem-solving and learning skills as well as the ability to use technology and engage in real-world tasks (see Bell, 2010; Binkley et al., 2012; OECD, 2010). These are regarded as core skills in the knowledge society as well as in work life. Students should embed these skills when completing their basic education in order to be ready for further studies and in taking steps towards work life. Work life is changing rapidly in all of society; therefore, we cannot prepare our children for something that is not yet known. However, equipping them with the skills that will enable them to manage is the best measure we can take. With the availability of information and technology, the skills on how to get information on what is needed, how to utilise it and how to make the best of technology, we can create the ecosystem around this project whereby we can practice these skills in a safe environment.

The eCraft2Learn ecosystem will support both formal and informal learning by providing the appropriate digital fabrication, making technologies and programming tools. It will also incorporate mechanisms for personalised and adaptive learning. The eCraft2Learn project will deploy a craft- and project-based methodology, a combination of *inquiry-based learning* with *design thinking* through the use of *DIY* and *3D printing technologies* in order to enhance the pedagogical outcomes of the individually applied inquiry-based and design thinking methods.

The eCraft2Learn concept is based on the premise of *learning by making*. Learning by making approaches have their roots in the constructivist theory of knowledge and constructionist educational theory. Constructivism is based on the proposition that knowledge is generated from the interplay between ideas and experience (Piaget, 1976).

The eCraft2Learn project aims to implement cross-disciplinary project-based pedagogies through the use of the educational ecosystem that the project will integrate. Within the eCraft2Learn educational ecosystem, students will have the opportunity to repeatedly explore the underlying mechanisms for some scientific phenomena or engineered artefacts. Within the eCraft2Learn ecosystem, deeper learning will involve an integrative perspective in order to approach a given making task. As for art and music, deeper learning involves not only artistic expression but also asking questions about aesthetics, taste, fashion, history, culture, etc. Deeper learning in STEAM also brings in history and aesthetics. The eCraft2Learn ecosystem will enable a seamless integration of art and natural science subjects, for instance, into technical subjects, through a combination of digital technologies and project-based learning methodologies.

2 THEORETICAL FOUNDATIONS

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

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

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

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

STEAM provides a way to engage boys and girls of all ages to explore the idea of electronics and technology (Magloire & Aly, 2013). The inclusion of arts and craft in science projects enables a space for creativity and innovation during the process. Electronics and technology usually attract more boys than girls, and girls have traditionally been more attached to artefacts when the product was meaningful to them (Magloire & Aly, 2013). According to Fristoe, Denner, MacLaurin, Mateas and Wardrip-Fruin (2011), girls' interest in creating games is mainly in the context of *relationships, social interactions and storytelling*. Therefore, working in teams could fascinate girls because of the social interaction aspect (Mäkitalo-Siegl & Fischer, 2013) as well as arts and craft (Magloire & Aly, 2013) to work with projects involving electronics and technology. Weber and Guster (2005) have studied gender-based preferences towards technology. The population of their study consisted of middle school students and high school technology education classes. They found no differences in activity between genders; however, significant differences were found in relation to design and use. 'Females found design activities more interesting when males preferred utilising types of activities' (Weber & Guster, 2005, p. 59). Furthermore, a recent report on digital making activities and gender stated that 'since making is based on what is personally relevant to an individual, it allows people of all backgrounds to pursue their interests and to use technological tools to develop their own projects. It can create more channels for girls to positively identify with computer science and engineering fields' (Intel Report, 2014 p. 7). Table 1 presents the top five activities among male and female students.

Table 1. Activities rated most interesting by male and female students at middle school and high school levels (Weber & Guster, 2005, p. 61)

Male students	Female students
1. Build a rocket 2. Construct an electric vehicle that moves on magnetic track 3. Perform sample car maintenance tasks on a car engine 4. Program a robotic arm 5. Design a model airplane that will glide the greatest distance	1. Use a software-program to edit a music video 2. Using a computer software program, design a CD-cover 3. Design a model of an amusement park 4. Design a school mascot image to print on t-shirts 5. Design a "theme" restaurant in an existing building

Gender also has an influence on cooperation in groups. Previous research indicates that students' positive academic performance is connected to single-gender conditions (see Harskamp et al., 2008; Light, Littleton, Bale, Joiner, & Messer, 2000). This has been explained in terms of similar working manner as well as attachment (Greenfield, 1997; Newman, 1998; Whitley, 1997). However, there is also evidence that gender conditions have no influence on the performance of groups, even though it was found that there were differences in terms of acting between mixed-gender and single-gender groups (Mäkitalo-Siegl & Fischer, 2013; Underwood, Underwood, & Wood, 2000). Male students are reported as being generally more interested in computers; therefore, it might be easier for them to work together on computer-supported tasks (Greenfield, 1997; Newman, 1998; Whitley, 1997). Nevertheless, the use of *e-textiles*, for instance, to integrate arts and STEM education in computing education can broaden participation, especially among females (Peppler, 2013, p. 38). E-textiles are clothes or other textiles that include electronic components that are often woven in. The e-textile design includes creative coding, the artistic envisioning of material science and inventive electronics (see Peppler, 2013). There are several examples of how to modify clothes and shoes using electronic components on the internet. Using 3D-printing, micro processing technology and Arduino, students animate toys, clothing and art works without working on screen-based programming and more academic work, which does not appeal to all students. In this way, we can capture the interest of students who would rather do and make things within the new computer sciences[3].

3 STEAM EDUCATION AND ECRAFT2LEARN

The updated school curricula across Europe emphasise interdisciplinary pedagogical approaches and projects. As part of the field of computing and engineering, it is easy to combine robotics with basic skills in physics, electronics, programming and mechanics. A more difficult integration comes when the above-mentioned skills need to be combined with history, literature or religion studies. The eCraft2Learn learning ecosystem aims at enabling the integration between scholarly subjects. In their own projects, teachers and students can integrate different subjects, for example, visual arts, crafts, music and science. The integration of different subjects depends on the context in which the experiments will be implemented, and therefore, teachers and students are in a key position to work with a combination of subjects in their projects.

The 'STEAM concept is an educational curriculum and an abbreviation of Science, Technology, Engineering, Arts, and Mathematics. STEAM connects and integrates these particular school subjects. STEM disciplines can benefit from an artistic infusion that connects disciplines in ways that are powerful and motivating for learning' (Henriksen, 2014, p. 4). STEAM has also been approached through art-based projects. Guyotte, Sochacka, Costantino, Walther and Kellam (2014) have examined an art project that focuses on complex local and global sustainability design challenges. This STEAM project provided students with 'a possibility to think through materials, consider audience, and engage with the community brought forth a framework of social practice as doing' (p. 19). While art as a social practice may trace its aesthetic roots to John Dewey's *Art as Experience* (1934), recent scholars have also called for art to become a critical component of social life (p. 13).

In a study by Laamanen (2015), there is an example of how different school subjects can be integrated into a *theatre robotics project.* Students designed, constructed and replayed a narrative or theatre chapter with educational robotics within similar pedagogical and technical frameworks to the eCraft2Learn pedagogical framework. The multidisciplinary nature of the project enabled the integration of various school subjects like history, literature, religion, arts, ICT, mathematics, physics and sports. Thus, in this project, we aim to enhance and support students' activities step by step by

3 see https://www.createeducation.com/blog/code-create-corelli-college/

offering pedagogical methods and embedded technology as well as the whole ecosystem for student use, which will be introduced in the following section.

4 Craft- and Project-Based Learning Methodology in eCraft2Learn

The eCraft2Learn project will deploy a craft- and project-based methodology, a combination of the inquiry-based approach with design thinking through the use of DIY (do-it-yourself) and 3D printing technologies, in order to enhance the pedagogical outcomes of the individually applied inquiry-based and design thinking method (see Figure 1).

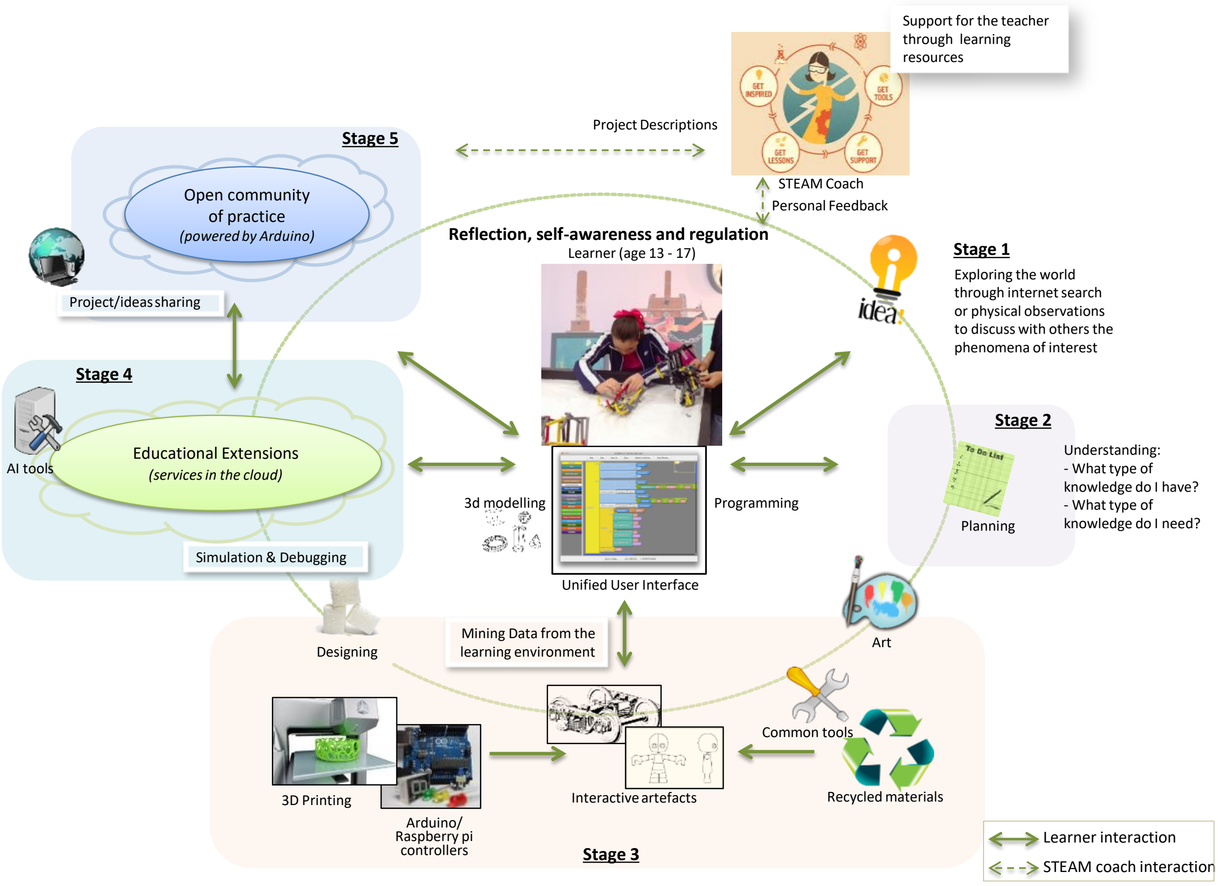

Figure 1. eCraft2Learn ecosystem indicative scenario

The eCratf2Learn craft- and project-based learning methodology follows the ideas of design thinking and project-based learning processes (see Figure 2). Inquiry-based learning usually starts with students posing questions, problems or scenarios, and the process is supervised by a ‘coach’ (teacher acting as a coach). Students identify study issues and formulate questions in order to develop their knowledge or solutions. The process is intrinsically argumentative whereby the students create questions, obtain supporting evidence to answer these questions, explain the evidence collected, connect the explanation to knowledge obtained from the investigative process and, finally, create an argument and justification for the explanation. In order to enhance this process of inquiry, we draw from the design thinking method as a hands-on counterpart.

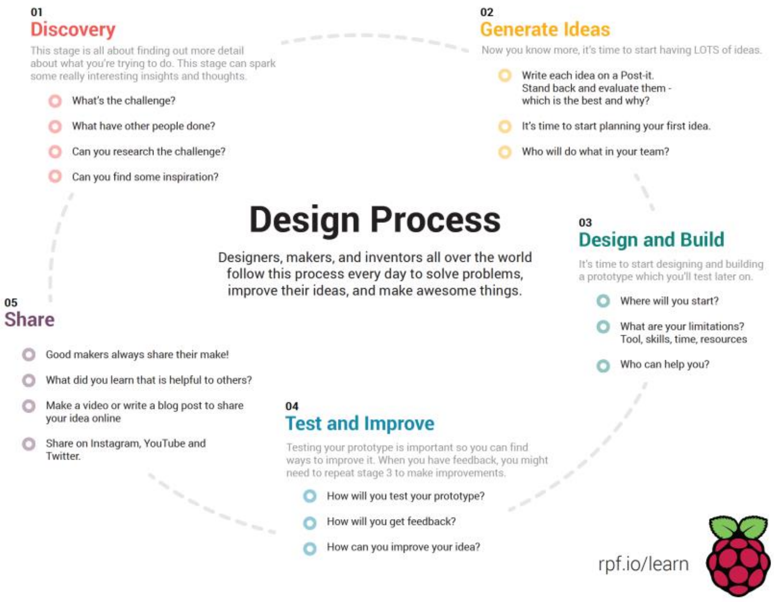

Figure 2. Five stages design process from the Raspberry Pi Foundation[4]

Activities occur in groups and on an individual basis (Dillenbourg & Fischer, 2007). Reflection and evaluation are conducted at every stage, which might be during each stage or at the end of each stage. The purpose of reflection and evaluation is to influence when these activities occur. Reflective practice is used in the field of arts and design. Here, Boud, Keogh and Walker (1985) modified Dewey's ideas on reflective thinking, identifying three perspectives on reflective thinking: (1) experience, whereby the learner is clearly acknowledging the observed events, (2) recognising or connecting feelings by strengthening positive feelings and disguising negative ones and (3) evaluation. Experience is evaluated on the basis of the goals set and prior knowledge. At the same time, the learner actively connects new information to prior knowledge (Boud et al., 1985; De Freitas, 2002). Reflection can be performed individually or in groups. 'Evaluation taking place in groups means that the members of the group will direct their attention at both subjective and intersubjective issues' (Anttila, 2006, p. 78). Reflective thinking also supports learners in personalising their own learning paths in this way. Personalised learning is enabled through paths situated on the working platform. Paths are for learners with diverse backgrounds and previous skills, for example, in programming. These paths help students to develop and create the planned artefact.

4 https://s3-eu-west-1.amazonaws.com/raspberrypi-education/teaching-physical-computing/Design-Process.pdf

4.1. Roles in eCraft2Learn ecosystem

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

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

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

The eCraft2Learn working platform is easy to approach and use. The platform encourages the learner to share thoughts and ideas. It contains videos on creating DIY artefacts and references for accurate information. At the same time, the platform works as a portal where earlier projects are documented. On the eCraft2Learn working platform, there is a chance to get online help from an expert who has the requisite knowledge. Experts encourage students to ask questions and present their ideas. Experts give concrete examples, share their own knowledge and expertise and give constructive and positive feedback. In the online platform, students can utilise carefully planned prompts in order to help them to proceed to each stage. The design of the working platform is visually tempting and is made to respond to girls' interests.

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

4.2. Five stages of craft- and project-based learning

We present here the five stages of craft and project-based learning (see Figure 3). However, depending on students' previous experience, prior knowledge and skills, the plan is not to follow these stages on a strict step-by-step basis. It might be that students want to first explore programming before starting to define their challenge. Thus, for novice students, it might be easier to start the project in a more instructional manner. Next, we detail the stages and activities that the students are supposed to perform in each stage and how the teacher, the embedded technology and the whole ecosystem can provide support for students at each stage as well as the possible pitfalls of each stage.

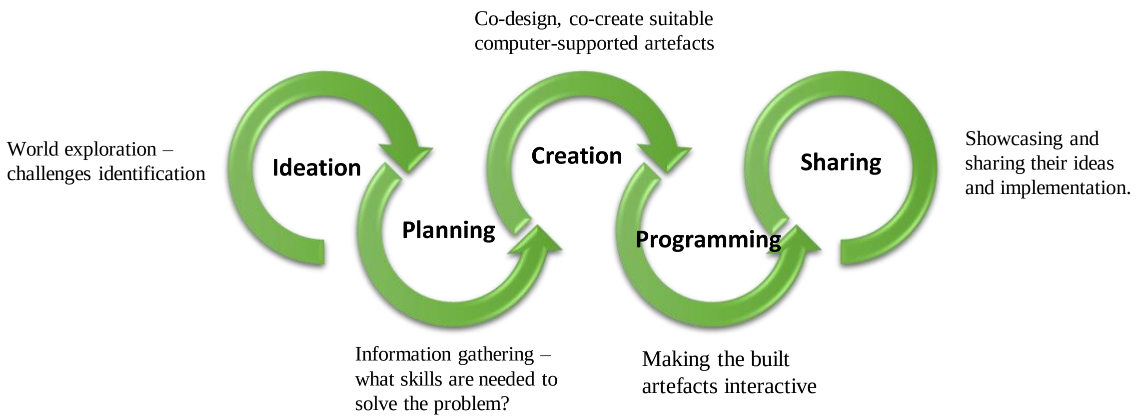

Figure 3. Five stages of craft- and project-based learning methodology for eCraft2learn

Stage 1. Ideation through world exploration

In order to explore the kinds of challenges that students or others face in their daily lives, a student could explore the world physically (e.g. taking pictures, exploring situations outside the classroom, newspapers, etc.) or virtually (e.g. through online support community discussion, online news, documents, local news/websites) and then decide what their challenge/problem will be. This process is also guided by the STEAM coach.

A project can be a problem to solve, a phenomenon to investigate, a model to design or a decision to make (see Yetkiner, Anderoglu, & Capraro, 2008). In considering of students, projects should be realistic and meaningful (see Helle et al., 2006; Thomas, 2000). Involving students in defining their own challenge or problem as well as goals and the steps on how to reach these goals will better engage them in their own learning process. The ability to influence and choose their own goals is connected to students' success. Choice enables deeper learning on the level of the student and encourages them to become engaged in the process (see Bell, 2010.) The process and its foundational problem should be anchored in a real-world problem. The process should include various design paths. In general, it would be good for students in order to enable possible flow during the project that they set their goals at each stage and on a daily basis. By setting daily goals, students will learn how to evaluate the progress of their process. Setting goals gives students the possibility to use their time effectively and an opportunity to report their proceeding after every working session (see Bell, 2010).

Defining the problem/challenge

Students will explore the world virtually and physically, including the kinds of phenomena or challenges they face in their everyday lives. By exploring the world, they define the problem or challenge. They can step out of the classroom, observe people (or things) in their everyday action and find challenges in them. At this stage, students' aim is to find out more detail about what they are trying to do. Students should 'step into people's shoes' – taking on a role – to see what they need and what they feel. It might be worthwhile to give the students a theme, for example, 'recycling', in order to guide their inquiry process and focus.

<u>Guiding questions</u>: *What is the challenge/problem? What has been done by other people before? Can you study/explore the challenge/problem? Are you able to find inspiration?*

The problem definition could be started with conversations in groups, mind mapping, making a collage, observing, taking notes or with other techniques that students regard as meaningful. According to Grant (2002), students should be able to present what they have learnt through the construction of an artefact. This could happen, for example, through a multimedia presentation or a poem (see Harel & Papert, 1991; Kafai & Resnick, 1996).

- Ideation can be done through brainstorming or other similar techniques. The teacher encourages students with slogans such as 'the craziest ideas are the best' and 'the sky is the limit'.
- At this stage, it should be emphasised that students can let their ideas run freely and that they can select the best one for their implementation stage.
- The teacher supports the learning process by posing open-ended questions and helping students make their thinking visible. The teacher keeps the students working for the group process (Hmelo-Silver, 2004). If defining the problem is difficult for students, they can use the

prompts in the eCraft2Learn working platform (online help), or the teacher can lead the discussion by asking the following questions (which are the same as in the prompts): *'What are the needs of a human being?' 'What kind of invention would help you in your everyday life?' 'What kind of everyday challenge would you solve?'*

- To maintain the students' focus, the teacher can suggest a theme, such as 'fashion', 'recycling', or 'loneliness', and based on this theme, the students can locate a challenge in their surroundings and start to find a solution to it.
- Through brainstorming and the use of the improvisation exercise called 'YES! And...' – This is an open assignment, and there are no complete answers. Students approve all the crazy suggestions they get. In addition, they bring their own ideas by processing old ones, bringing in something new. These improvisational exercises are widely used to enhance the effectiveness of brainstorming (see Gerber, 2009).
- Through additional methods for ideation such as SWOT analysis (listing the strengths, weaknesses, opportunities and threats), metaphors, question lists (Väänänen et al., 2016), etc.
- Students explore how the challenges of everyday life have been solved through the use of robotics. They can pick interesting videos and material from the working platform and can share the videos and discuss them: *'What is robotics in the first place?'*
- Ideation could be developed in the virtual world where students can be emotionally and informationally supported through their process (see Kitsantas, Dabbagh, & Dass, 2013).
- The virtual world can support students' increasing academic- and technology self-efficacy, develop intrinsic motivation, provide feedback and tangible resources and promote collaboration and interaction (Kitsantas et al., 2013, p. 92).
- Students can reconsider the initial problem/idea based on the experiences they gain. The student groups encage to solve particular problems, explore multiple solutions and provide reasoning concerning the artefact they wish to develop, reflecting on the best and why.

After defining the problem, the ideas are briefly presented in the whole group and discussed. In this presentation, experts can also be involved, clarifying, reflecting, evaluating, supporting and motivating students working on the solution to their challenge.

Table 2. Ideation stage - roles, working methods, and technology in the craft- and project-based

	IDEATION
STUDENT (role)	notetaking, conversation in groups, mind mapping, making collage or with other technique SWOT-analysis can be used to perceive possible strengths, weaknesses, opportunities and threats *Students must have the responsibility for their own learning* (Savery 2006) Students define the problem through conversation, making notes, taking photos. **What kind of challenge do we want to solve through this artefact? *(save the nature, recycle, bring joy to other people around us, to create an intelligent and safe jogging outfit for the dark wintertime...)***
TEACHER (role)	Teacher is guiding the learning process through open-ended questioning designed to get students to make their thinking visible and to keep all the students involved in the group process (Hmelo-Silver 2004). Teacher encourages the students to develop the idea.
eCraft2Learn- PLATFORM/ EXPERT (role)	Teacher can guide students to use the prompts (situated on the working platform) which can include questions and/or crazy ideas of robotics that would make the everyday life easier. Working platform includes a glossary about the concepts like 3D printing, DIY electronics and other that concern the applications that students will use during the project. **What have other students done?**
TECHNOLOGY	laptops, smartphones, web browser, google drive, O365, logging accounts The use of DIY (do-it-yourself) and 3D printing technologies are in order to enhance the pedagogical outcomes of the individually applied inquiry-based and design thinking method (see Figure 1).
PITFALLS	Creating the ownership Students use resources that are appropriate for their individual reading levels and compatible with their technology knowledge (Bell 2010, p.41).
REFLECTION AND EVALUATION	students can choose, how they want to report/reflect (video diary, portfolio, animation) Reporting and reflecting is made after every stage Documentation > could the students document their project (visually, photos and video material) > no language needed on presentation/reporting? *"What did we know about this phenomenon? What did we find out?", What do we still need to know?"* *"Why do we want to create this artefact?"* Reports are being shortly presented after every stage

When ideation does not proceed smoothly

- The teacher can guide students to open the prompts, situated on the eCraft2Learn working platform, which can include questions (e.g. *'What do we know now?' 'What do we have to* *find out?')* and/or crazy ideas (and videos, photos) about robotics that would make everyday life easier.

- The teacher will guide students to think about *'What do we know now?' 'What do we have to find out?'* and to define their challenge.
- Experts can open up the process of ideation via podcasts, videos and chat in terms of how one comes up with these 'crazy' ideas – motivational aspect, inspiration.

Good to know: The study of Boling and Smith (2014) states that a student designer is capable of working as an expert if he has a proper learning experience of the background. They also claim that it would be more fruitful to support the student with one idea than by making him produce many different ideas. Through the commitment and ownership of an idea, the student is ready to find varied paths to succeed. Boling and Smith (2014) have studied novice designers' (students) design activities. They observed that every student had a unique style to proceed. A clear mechanism of using these styles was not found, but it seemed that their personal proclivities towards acting and that previous experiences of working and studying had an influence on the patterns.

This ideation round ends once again with discussion and getting feedback from experts about the idea for the project. At the end, the teacher asks students to reflect on what they have learnt during this stage, what they thought and what remains to be learnt.

The aim of this stage is for the students to ideate artefacts in groups by exploring the world and phenomena. They define the challenge and reason why they want to create this particular artefact (see table 2). After ideation, they are ready to step into stage 2.

<u>Stage 2. Planning</u>

Once the challenge has been defined, students start to collect information to make a project plan. This consists of a work timeline, materials and tools as well as the assigning of roles – they could get feedback from the STEAM coach on their project plan as well as on the roles for group members. At the beginning of this session, students are instructed to set goals. Goal setting helps them to progress with their activities as well as to reflect on their activities and the learning process at the end.

- In the planning phase, the student chooses the project and finds the resources. Through these activities, the student identifies and gathers information and creates a potential solution. There will be the list detailing the planning, including a roadmap.

- Students can alter or extend their initial project idea, personalising the learning experiences in line with their interests and needs towards a more self-directed approach.
- Students search for resources, investigate alternative solutions and familiarise themselves with the technologies, devices and software available in the eCraft2Learn ecosystem.
- Online communities (Facebook groups, Snapchat, social media) and expert/teacher/coach can be called upon to promote the planning stage (padlet, popplet, mindmap, etc.).
- On the eCraft2Learn working platform, different paths can be chosen to implement the planning. These paths provide opportunities for students with varied skills (everyone has a chance to succeed).
- The planning stage can be integrated with handicrafts, visual arts (and music). Plans can be presented with (audio-)visual material by making animations, for example. At this stage, different prompts can be opened to trigger the planning.
- Prompts (help/support) can be situated on the eCraft2Learn working platform, which can be in the form of:
    - **Questions** (which are located on the working platform) force the student to ponder the idea of the artefact and productive process: *'Who can take advantage of this product?' 'For whom are we planning this?' 'Why are we planning this?' 'What is the benefit of this artefact?' 'Is it usable regardless of the place?' 'How are you going to sell the product?' 'What is the best way to build the product?' 'What kinds of expertise do we have in our group?' 'What kinds of expertise/knowledge/skills do we need to make the artefact?' 'What kinds of technology and material do we need?'*
    - **Short video clips** in which experts working in the innovative design team tell and demonstrate how they work in the planning stage.

- The teacher introduces different materials and tools on what is available for them in the eCraft2Learn platform and in the classroom. They select materials and tools for use regardless of whether they are able to use them.
- Write ideas on a Post-it, stand back and evaluate them – which and the best and why?
- Start the planning step by step. The teacher helps with the questions and advices on ideas. This could also be with the help of peers.
- More advanced groups can present what they have done so far.
- Learning Café method: Groups have their own tables where a member of the group is available at the whole time, and the other students change between the tables and give some ideas to the planning stage.

Table 3. Planning stage - roles, working methods, and technology in the craft- and project-based learning methodology

	PLANNING
STUDENT (role)	21st-century skills include of skills of collaboration - negotiation and communication - and creativity, critical thinking, problem-solving and learning to learn skills as well as ability to use technology and engage in real-world tasks (see Bell, 2010; Binkley et al., 2012; OECD 2010) student works as an active member of the group, bringing his/her own previous knowledge notetaking, setting goals, reflective Students set a target for their working and organise the division of labour. **What do we need to make this thing work? Material? Where can we get it? How do we start to create it? Where can we get the information of DIY-technology?**
TEACHER (role)	Teacher supporting students' planning, for example, providing the check-list of planning, concrete questions regarding planning stage, work division, materials, the skills and knowledge of group members, the lack of skills and knowledge
eCraft2Learn- PLATFORM/ EXPERT (role)	On the eCraft2Learn working platform, different paths can be chosen to implement the planning. These paths are providing chances for students with varied skills Expert can be reached through working platform
TECHNOLOGY	web browser, google drive, O365, planning tools, selected apps in smartphones
PITFALLS	identifying all important elements needed for implementing the project, defining the skills and knowledge needed
REFLECTION AND EVALUATION	***"Did we reach our target?" "Is our plan complete to start the creation?"***

At the end of step 2, the students give short presentations of their project plans and the idea of the product they are creating. Plans are edited based on feedback from the audience (peers, teachers, experts). At the end, the teacher asks students to reflect on what they have learnt during this stage and what they thought still needed to be learnt.

The aim of this stage is to collect information, make a project plan with a work timeline, collect materials and tools and assign roles. Setting goals is important as well as getting feedback from teacher and peers.

Stage 3. Creation

In this stage, the students embark on the co-design and co-creation of their computer-supported artefact solutions through the application of DIY technologies. The visualisation and simulation of the designs are also an important part of this stage. In starting the creation stage, students set their goals for this stage in order to organise their work. They will be asked to reflect on their set goals at

the end of this stage and evaluate how well they have reached these goals, in what ways they were successful and what hindered their success.

The design of an artefact is a collaboration among the students, teachers and experts involved. The production of an artefact, which is readily sharable with a larger community of learners, encourages students to make their ideas explicit. It allows them to experience science concepts in a meaningful, personalised context. By participating in both independent work and collaboration, learners improve their problem-solving skills, thereby developing their critical thinking skills as well as creativity.

Instead of the 'black box' metaphor, the 'white box' is preferred. The black box is compatible with the traditional educational model of the teacher or curriculum explaining ready-made ratified, and thus unquestioned, information. Artefacts where users can construct and deconstruct objects and programme them from scratch enable a deep structural access to these artefacts. This generates considerable amounts of creative thinking and involvement from learners.

In starting to design and build a prototype (which will be tested later), the group should think about where to start, what are the limitations regarding tools, skills and time resources and where and from whom to get help.

- Especially during this stage, students (and teachers) need support from experts; videos can include material demonstrating how the experts start their design process. Videos could also include information about how different materials act
- The teacher needs to encourage students to explore, and the role of an expert is to help students to get over challenging operations.
- Possible pitfalls: Boling and Smith (2014) claim that students with inadequate knowledge of tools are not capable of working with the conceptual issues in design.

According to Fox (2014), Third Wave DIY websites enable the combination of the read-write functionality of Web 2.0 with computer-aided design (CAD) and digitally-driven manufacturing equipment such as additive manufacturing (AM) machines (e.g. 3D printers) and/or computer-numerically-controlled (CNC) routers. Third Wave DIY websites enable interaction among individuals at different locations (Fox, 2014, pp. 19-20). The social learning associated with Web 2.0 (see Seely & Adler, 2008) can be facilitated through the blogs, forums, wikis, etc. of all these websites (Fox, 2014).

Table 4. Creation stage - roles, working methods, and technology in the craft- and project-based learning methodology

	CREATION
STUDENT (role)	Students design and build the artefact peer learning across the group boarders **Students set a target for their working and organise the division of labour.** **How are we getting organised, who is doing what?** **Where can we get instructions for creating this 3D-thing? How do we start?** **What type of knowledge do we need?** **From where can we get it?**
TEACHER (role)	solving the challenges together with students helping students to find suitable paths (eCraft2Learn working platform)
eCraft2Learn- PLATFORM/ EXPERT (role)	It´s expected that the students need support especially on this stage (expert online/ eCraft2Learn working platform)
TECHNOLOGY	DIY technologies. Visualisation and simulation of the designs 3D printing "Technology as a means, not an end, enables students to experiment with different technologies for all the aspects of PBL" (Bell 2010, p.42)
PITFALLS	Boling & Smith (2014) claim that students with inadequate knowledge of tools are not capable of working with the conceptual issues in design.
REFLECTION AND EVALUATION	*"What were the difficulties during creation? What did you learn about yourself as a member of the group during this stage? How did you succeed to work as a group?"* ***"Did we reach our target?"***

When there is no advancement in creation

- The teacher can ask students to build an experimental model of their artefact before the final version and ask them to observe how the materials act and what they need to be concerned about when creating the final version. For the second round, students can correct and improve their artefact.
- Students can explore the videos on how to design and build different artefacts.
- Students can be asked to simply draw their model on paper.
- Learning Café method – other group members visit the table of each group in order to help and give hints on how to go on with the creation.
- On the eCraft2 Learn platform, different DIY technologies are being presented on what has been done previously. Students can combine the ideas of previously built artefacts.

Enhancing the creation process

In this stage, each group can decide to have a role for each group member. Each group can be composed of, for example, 1 project manager and 1 3D wizard and a *tech team* of 1 coder and 1 circuit engineers[5].

Students introduce their design and receive feedback from their peer learners, teacher and experts. At the end, the teacher asks students to reflect (portfolios, evaluation e-form) on what they have learnt during this stage and what they thought still needed to be learnt. Students are asked to reflect on their set goals at the end of this stage and evaluate how well they have reached these goals.

The aim of this stage is to create computer-supported artefacts through the application of DIY technologies and to visualise and simulate designs. Moreover, reflecting on the set goals and evaluating one's own work are an important part of this stage.

Stage 4. Programming

Once the computer-supported artefacts are built, the students define suitable scripts (high-level programming language) for the functioning of their artefacts. Software debugging and integrated SW/HW simulation are two of the other steps in this stage. Students set their goals regarding programming and reflect on these goals at the end of the programming stage.

'What if' experimentations are encouraged through programming and the change of defined parameters. In this way, learners are challenged to explore alternative solutions and explore in depth the underlying scientific concepts.

- Prompts can offer different coding software or coding languages
- Educational videos, including programming
- Automated support – testing and pointing out mistakes or errors
- Experts helping students with the coding
- Knowing something old; integrating and learning something new
- Problem-solving, testing, experimenting – solving, testing, experimenting – evaluation
- The teacher can use a gamification approach to teach simple programming rules
- Students can learn programming with simple game apps

5 https://www.createeducation.com/blog/code-create-corelli-college/

- Possible pitfalls? The outcome of programming is not what is expected. It might be overly complicated programming language or overly simple in terms of achieving what was planned.

Table 5. Programming stage - roles, working methods, and technology in the craft- and project-based learning methodology

	PROGRAMMING
STUDENT (role)	peer learning across the group boarders learning, programming, rules, using programming language, do the programming **Students set a target for their working and organize the division of labour.** **What tools do we need for programming? What is programming?** **Where can we get instructions for doing this?**
TEACHER (role)	leads the students to eCraft2Learn working platform to find the right path
eCraft2Learn- PLATFORM/ EXPERT (role)	Blocks can offer different coding software or coding languages Automate support - testing, pointing out the mistakes or errors Experts helping students with the coding
TECHNOLOGY	e.g., Raspberry pi, Basic, Logo, Pascal, Python, Ruby, Visual Basic, C (family), Processing, JavaScript, HTML 5, Snap, Scratch
PITFALLS	students lack previous experience teachers capability to help in programming
REFLECTION AND EVALUATION	***"What was your first idea of programming and how did it change?"*** ***"Did we reach our target?"*** ***"What did we notice while testing our prototype?"*** ***"Can we improve our idea?"***

When there is no advancement in the programming

- The teacher can encourage students to experiment with the programming in order to guide them on how it works and ask them to develop it further.
- An advanced peer learner can act as a tutor with programming.
- Coding games can be used to help students understand the logic of coding.
- Break the programming into smaller sub-tasks in order to help the programming process.
- Use of videos available on the platform.
- Students could think of how to test the prototype, how to get feedback and how to improve the idea. When the test results are not satisfactory, an earlier stage might be repeated in order to make improvements.

At the end, the students can present what they have achieved with their programming, and they can test and remodify it. The teacher then asks students to reflect on what they have learnt during this stage and what they thought still needed to be learnt.

The aim of this stage is to programme computer-supported artefacts and define the suitable scripts for the functioning of these artefacts. Students can test and improve their ideas. The goals for working are also set and reflected.

Stage 5. Sharing

In order to enhance motivation and presentation skills, students are encouraged to share and showcase their projects and implementation ideas: 'Good makers always share their make!' This will be done through the open (online) community or through eCraft2Learn dissemination events. In return, they will receive feedback from artists, designers and engineers from around the world as well their peers. They will also participate in eCraft2Learn dissemination events where they will showcase their projects to the community in general.

This stage includes reflection and follow-up on the projects. Through sharing, learners obtain feedback and reflect on the learning process and their project/product, activating new cycles of design, construction and programming. This also leads to new ideas and refinement of their projects, finally resulting in a 'creative thinking spiral' (Resnick, 2007).

At the end of the project, students should evaluate what they have learnt and how they succeeded in cooperation. Students reflect on how they succeeded with regard to their peer group – how they listened and how their suggestions were heard (Bell, 2010). Students answer the question: 'What did you learn that is helpful to others?'

- In the prompts, students can find different types of presentation forms and applications for an effective communication style.
- There are guidelines regarding what they should take into account when presenting their product.
- Preparation stage: Before stepping in front of a larger audience, the teacher, experts and peer learners practice their 'elevator pitch': 'Why is this important?' 'What problem/challenge will our artefact solve?' 'For whom is our artefact designed?'
- Presentation: the material needed include posters in electronic form, animations for presentation and talks, etc.
- Students can make a video or write a blog post to share the group's ideas online.

- Students and teachers can share on Instagram, YouTube and Twitter.
- Evaluation, peer feedback, expert feedback and group evaluation.

Table 6. Sharing stage - roles, working methods, and technology in the craft- and project-based learning methodology

	SHARING
STUDENT (role)	small group, whole group, teacher, to the audience outside of the classroom student gives feedback to other students students can ponder which forum would be the best place to share their own project preparing the presentation practicing the presentation Exhibition, fashion day "Recycling" - theme Students can estimate their workload and choose takes the main responsibility of representing the project
TEACHER (role)	gives feedback to students
eCraft2Learn- PLATFORM/ EXPERT (role)	gives feedback to students description of the process (report) will be shared on working platform for next designers
TECHNOLOGY	the project website, other forums, Pinterest, video, blog
PITFALLS	Presentation is not efficient, too long and unclear - not aimed at the correct target group - and not well-practiced, this stage is overlooked
REFLECTION AND EVALUATION	Introducing the artefact to broader audience and sharing the report eCraft2Learn dissemination events *"What kind of an experience this project was? How would you further develop your artefact? If you began the same project from the start what would you do differently?"* *Students reflect how they succeeded in regarding their peer group - how they listened and how their suggestions were heard. (Bell, 2010)*

When sharing does not proceed in a smooth/easy manner

- Students and teachers can together think about events at which they can share their projects, for example, family evenings, a small event for other classes during breaks, local events, or the events can be organised by the students.
- Makers and designers (video) can tell students why good makers always share their awesome things.
- Improvisational practice (selling something which is a complete out-of-mind idea).

- Practising and sharing the other group's artefact (the other group has good ideas, and the presenters might be less stressed when presenting the other group's artefact).
- At the end of this stage, the teacher asks students to reflect on what they have learnt, what they thought still needed to be learnt, what they learnt that could help others, what would be the next challenge, what elements inspired them in the project, etc.
- Finally, students get to reflect on the entire project, the individual stages and the product. They also reflect on how well they performed different activities at different stages, how well they achieved their goals, and they evaluate their project outcome and the artefact they designed.
- The aim of this step is to present and share what has been created. Students receive feedback from artists, designers and engineers from around the world and from their peers. They evaluate how well they succeeded and achieved their goals.

5 CONCLUSIONS

The aim of this report was to develop the eCraft2Learn pedagogical framework for an appropriate craft- and project-based learning methodology to deploy our tech core. The eCraft2Learn pedagogical framework combines craft- and project-based technologies and the basic idea of STEAM (science, technology, engineering, arts and maths) education. This deliverable gives guidelines on how to implement craft- and project-based learning in teaching practice, and therefore, it serves as the basis for our teacher manual and in-service education courses for the teachers planning this EU project.

The framework is developed within five stages and is based on the idea of project-based learning and open learning scenarios: (1) Ideation, (2) Planning, (3) Designing, (4) Programming and (5) Sharing. The student' learning process is supported at every stage using the designed eCraft2Learn working platform and proper technologies, which are part of the learning ecosystem, as well as by teachers and experts. After each stage, the student regulates and reflects on his/her own learning before proceeding with the project. Through the working platform, students can choose their personalised learning pathways. Makers and designers all over the world follow this kind of process every day to solve problems/challenges, improve their ideas and make cool things. Enhancing early-stage skills can be considered fundamental for future professionals, such as system thinking, problem solving, adaptability and creative thinking. This kind of pedagogical approach we are providing here, whereby coding and creating are integrated, aims to create opportunities for students in the creative sector. Students are encouraged to engage with coding while they develop coding skills and creative thinking alongside problem solving in the learning process, in addition to adopting project management skills (see also https://www.createeducation.com/blog/code-create-corelli-college/).

The eCraft2Learn pedagogical framework serves the idea of twenty-first century skills, supporting students' creativity, entrepreneurship, critical thinking, collaboration skills and computational fluency (Dede, 2010). The framework encourages students, especially girls, to enter the field of science and technology.

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