Designing Seamless Learning Activities for School Visitors in the Context of Fab Lab Oulu

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Abstract: Maker culture has expanded from its traditional niches (people with an interest in computers, programming and the digital world in general) to other, more general fields such as education, business and government. However, “despite the interest in the Maker Movement and its connection to formal and informal education, there has been little research concerning the direction it is taking, the opportunities it could present for education, and why” (Papavlasopoulou et al., 2017). In this chapter, we developed a pedagogical framework for seamless learning in Fab Lab activities based on the multiple levels of interactivity that different tools, activities and the contexts enable. The aim is to use age-appropriate activities and appropriate tools, as suggested by Blikstein (2013). In this chapter, we introduce the theoretical principles of the framework – computational thinking, computational making and design-driven education – as a model to teach twenty-first-century skills. We also illustrate the pedagogical principles with a case study in a primary school (K-12) as an example of designing integrated educational activities to align with the maker activities being performed in the Fab Lab context.

Introduction

During the last two decades we have witnessed the flourishing of the Maker Movement. Maker is a term recently coined for individuals or groups of people who produce digital or tangible objects utilizing technological and digital tools. In particular, the making process includes constructing activities and related ways to fabricate real and/or digital artifacts using technological resources, including fabrication, physical computing and programming (Papavlasopoulou, Giannikos & Jaccheri, 2017). As Dougherty (2012) notes, the Maker Movement, as such, was born with the publication of *Make:* magazine in 2005 and has created an interconnected network of enthusiasts who engage and collaborate with each other, sharing knowledge and tools.

Nowadays, maker culture has expanded from its traditional niches (people with interest in computers, programming and the digital world in general) to other, more general fields such as education, business and government. In parallel to the Maker Movement, MIT professor Neil Gershenfeld conceived the idea of Fab Lab in 2003. Gershenfeld (2012) presents a Fab Lab as a small-scale workshop equipped, at least, with a set of standardized equipment including a laser-cutter, 3D printer, large and small computer-controlled milling machines and other materials (including components for molding and casting and to build electronics). All the machines are connected by custom software.

A Fab Lab is a component of the maker culture, which emphasises the personal manufacturing of physical items (generally from scratch) by means of computer-controlled equipment (Colegrove, 2013). According to Milara, Georgiev, Riekki, Ylioja, & Pyykkönen (2017), typical activities in a Fab Lab include:

1) Designing 3D and 2D parts. This incorporates the software and other tools which are utilized to design two-dimensional parts, such as those that are typically cut with a laser cutter, or 3D parts, such as those typically designed to be 3D printed.
2) Prototyping with electronics. This includes hardware design (electronics schematics and layout design), including its fabrication and soldering the components.
3) Programming. This incorporates the basic programming of embedded systems with a high-level programming language.
4) Utilizing the tools and machines at the Fab Lab. This activity incorporates the use of Fab Lab infrastructure to make a particular prototype. It includes the utilization of the vendor's software to operate the machines.

The community is a foundational aspect of the Maker Movement in general, and of Fab Labs in particular. The standardization of machines and processes enables an active exchange of ideas, designs, tools, materials and software, permitting the replication of any project at any Fab Lab in the network (Walter-Hermann & Bunching, 2014). Fab Lab is an example of a making context that does not resemble a traditional learning environment (e.g. a formal classroom). It promotes self-directed and collaborative work, creativity, and problem-solving skills, as well as enhances computational literacy (see, for instance, Hsu, Baldwin and Ching, 2017; Bevan, 2017; Blikstein, 2013; Blikstein and Krannich, 2013). However, while making is often touted as something new – e.g. in STEM education – it has deep roots in the theoretical thinking of Piaget, Vygotsky and Papert, and in pedagogies advanced by Froebel, Dewey, Montessori and others "who have argued for the centrality of materials-based investigations for motivating and advancing student learning" (Bevan, 2017, p. 75).

There is a growing number of research into the possibilities of maker settings in K-12 education. Based on the literature, research on the topic can be categorized into three types. First, theoretical approaches to the Maker Movement (Halverson & Sheridan, 2014; Martin, 2015; Vossoughi & Bevan, 2014); second, descriptions of and potential uses for technological tools for educational purposes (Blikstein, 2013); and third, discussions about the types of learning interactions experienced in those settings (Papavlasopoulou et al., 2017).

A literature review by Vossoughi and Bevan (2014) identified three main categories of educational maker activities, each with distinct purposes and audiences as well as overlapping features:

1) *Making as entrepreneurship*. Fab Labs are one example of this category. They are fundamentally organized to support the production of things – to provide machines and other types of tools, such as 3D printers, that may not otherwise be accessible. Being in such a context fosters entrepreneurial mindsets in students who visit Fab Labs, and activities can be organized to provide supervised and (non)structured educative activities.
2) *Making to support STEM workforce skills*. These programs, which generally take place in secondary schools, may resemble technology education or design-based learning programmes in that they are more focused on problem-solving than play.

The curriculum is organized around project-based activities involving advanced tools such as 3D printers, vinyl cutters or welding equipment.

3) *Educative making* does not depend on, though it can make use of, dedicated makerspaces like Fab Lab; instead it is primarily a pedagogical approach to engaging students in design/build activities that allow them to explore ideas, develop skills and understanding within multidisciplinary disciplines, and build a wide range of learning dispositions and capacities. This approach has become popular in informal settings such as libraries.

At the University of Oulu, we draw on this research and undertake studies to help us gain a better understanding of the processes at Fab Lab and in educational settings, and to develop the most appropriate methodologies to produce consistent research data about these activities (e.g. Georgiev, Sánchez, & Ferreira, 2017; Iwata, Pitkänen & Laru, 2017; Sánchez, Georgiev, Riekki, Ylioja, & Pyykkönen, 2017)

In continuation of these research efforts, we developed a pedagogical framework for seamless learning in the Fab Lab that features activities based on the multiple levels of interactivity that different tools, activities and the contexts enable. With the pedagogical design, we bridge individual and collaborative activities in the different contexts while also combining face-to-face with online activities. The aim is to use age-appropriate activities and appropriate tools as suggested by Blikstein (2013).

We begin this chapter by introducing the theoretical principles of the framework – computational thinking, computational making and design-driven education – that serve as foundational properties of a model designed to teach twenty-first-century skills (see Table 1). We will go on to illustrate the pedagogical principles of the model with a case study conducted in a primary school (K-12). The case study serves as an example of designing integrated traditional and maker activities in the Fab Lab context.

Table 1

Three Frameworks that are Used as Theoretical Lenses for the Pedagogical Design of the Seamless Learning Activities

Twenty-first-century skills (Binkley et al., 2012)	**Computational thinking [CT] (The College Board, 2013)**	**Computational making [CM] (Rode et al., 2015)**
Ways of thinking ● Critical thinking ● Creative problem-solving ● Learning to learn Ways of working ● Communication ● Collaboration (teamwork) Tools for working ● Information literacy ● ICT literacy Ways of living in the world ● Citizenship: local and global ● Life and career	● Connecting computing ● Developing computational artifacts ● Abstracting ● Analysing problems and artifacts ● Communicating ● Collaborating	● Aesthetics ● Creativity ● Constructing ● Visualising multiple representations ● Understanding the materials

• Personal and social responsibility		

Computational Thinking and Computational Making in Makers Contexts

Many studies, starting from Seymour Papert's Logo programming language and Lego Mindstorms, showed connections between making and the learning principles of engineering, design and computer programming (Papavlasopoulou et al., 2017). Furthermore, the recent literature review "Empirical Studies on the Maker Movement, a Promising Approach to Learning" demonstrates that almost all the studies included into review had as their main subject programming or a combination of programming and math (Papavlasopoulou et al., 2017).

Grover and Pea (2013) argue that computational thinking (CT) is an important competency because today's students will not only work in fields influenced by computing but will also need to deal with computing in their everyday life. Yet the most cited rationale in the literature for including CT in K-12 instruction is the growing demand for citizens with computer science skills (Wilson & Moffat, 2010). In other words, CT can be considered an essential skill for twenty-first-century students (Wing, 2006).

In a K-12 context, several definitions have emerged for what CT entails in schools. Key in all these definitions is the focus on skills, habits and dispositions to solve complex problems with the help of computing and computers (see e.g. Voogt, Fisser, Good, Mishra & Yadav, 2015).

Barr and Stephenson (2011) describe core CT concepts and capabilities that could be embedded in K-12 classrooms. They suggest nine core concepts for CT in K-12 education: 1) data collection; 2) data analysis; 3) data representation; 4) problem decomposition; 5) abstraction; 6) algorithm and procedures; 7) automation; 8) parallelization; and 9) simulation. On other hand, Barr, Harrison & Conery (2011) define CT in K-12 contexts as a problem-solving process with the following characteristics: 1) formulating problems in a way that enables us to use a computer and other tools to help solve them; 2) logically organizing and analysing data; 3) representing data through abstractions such as models and simulations; 4) automating solutions through algorithmic thinking (a series of ordered steps); 5) identifying, analysing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources; and 6) generalizing and transferring this problem-solving process to a wide variety of problems.

Rode, Weibert, Marshall, Aal, von Rekowski, El Mimouni, & Booker (2015) critique these definitions because those consider desktop computers to be an environment of learning but does not embrace ubiquitous computing environments. They argue that Denning and Rosenbloom (2009) laid the grounds for a more comprehensive approach to computing by also embracing making. Rode et al. (2015) do, however, identify challenges in teaching pure CT skills in the context of maker activities: "as soon as we move from teaching computational thinking with a focus on desktop and software, to ubicomp and maker space . . . different skills are required. Knowledge of software is still critical, but so is knowledge of electronics, engineering and craft skills like sewing, drawing or carving. . . . we call for a broadened notion of computational making (CM) as the starting point for future STEAM (Science, Technology, Engineering, Arts & Mathematics) education" (pp. 238). Their suggestions for computational making skills appear in Table 1.

Although the suggestions made by Rode et al. (2015) are good in the context of maker activities, a key aim of CT is to end up creating either tangible or virtual artifacts through processes which include phases such as abstraction, recursion and iteration during processing, and analysing project-related data (Barr and Stephenson, 2011). Based on Barr and Stephenson (2011), CT is a skill that can be implemented in different educational contexts, including languages and arts as well as STEM classrooms. In other words, CT can be used to augment human creativity (Voogt et al., 2015), in particular with the use of automation and algorithmic thinking. According to them, CT can be used for creating new forms of expressions in activities which support creativity and where different tools are being built. The College Board (2013) operationalized ideas about problem-solving and creativity in their "Computer Science Principles Draft Curriculum Framework," in which they introduced six CT practices, which are presented in Table 1.This framework will be used in this chapter to illustrate CT in the context of Fab Lab Oulu, because it has elements which can be seen also in the framework of CM and design-driven education.

Computational thinking activities are natural parts of maker culture, design and fabrication, and they can be seen as vital elements of thinking and working in the context of Fab Lab. By using CT as a framework for pedagogical design, it is possible to combine the development of skills and knowledge, which in school contexts are traditionally isolated and taught in separate subjects (Pitkänen, 2017). Through multidisciplinary, collaborative and problem-solving-based learning projects, learning twenty-first-century skills can be applied to the context of maker activities. One model for accomplishing this is described in the following section.

Design-Driven Education as a Model for Teaching Twenty-First-Century Skills in Makers Contexts

The information society we are living in demands that we develop skills to adapt to new ways of working, living, learning and thinking. We increasingly need new skills to manipulate information-based work tools; to search, analyse, evaluate and apply information; and even more significantly, to collaborate and solve problems together (Griffin, Care, & McGaw, 2012).

Numerous countries and organizations have defined their own recommendations and frameworks of twenty-first-century core skills (see e.g. ATC21S project, n.d.; European Union, 2016; OECD, 2005; and Partnership for 21st Century Learning, 2015). In this chapter, we will use the international Assessment and Teaching of Twenty-First Century Skills (ATC21S, n.d.) framework to integrate twenty-first-century skills into pedagogical design (see Table 1). In this definition, ten future skills, called twenty-first-century skills, are divided into four broad categories: 1) ways of thinking, including critical thinking, creativity, problem-solving and learning to learn; 2) interactive and collaborative ways of working, including regulation of one's own and group activities and behaviors, 3) effective and meaningful use of tools for working and 4) ways of living – adopting responsible, participative, local and global citizenship in the world (Binkley, Erstad, Herman, Raizen, Ripley . . . & Rumble, 2012). In addition to that, design-driven education in school contexts is also seen as one way to develop collaboration and communication skills (Halverson & Sheridan, 2014), increase students' motivation by engaging them in authentic learning scenarios (Cross, 2007) and promote creativity among learners (e.g. Hargrove, 2012; Lau, Ng, & Lee, 2009).

The core idea of design-driven education is that students and teachers participate together in the planning, implementation and assessment of learning projects (Nelson & Stolterman, 2003; Hakkarainen, Mielonen, Raami, & Seitamaa-Hakkarainen, 2003). The teacher's role is to provide support and guidance to the students and to encourage their collaboration for finding relevant and innovative solutions to the learning tasks. Students are expected and encouraged to find solutions independently. The community and experts outside the school are also seen as essential collaborators in stimulating learning and assisting students to solve various real-life problems. Furthermore, students' personal interests and expertise have an important role in creating an engaging learning experience (Gomoll, Keune, & Peppler, 2015; Heikkilä, Vuopala, & Leinonen, 2017).

In the maker context, a design-driven approach can be fitted into making, which emphasizes STEM skills (Vossoughi & Bevan, 2014). This view into maker activities is rooted in design and construction; learning activities emphasise the development of students' twenty-first-century skills, such as problem solving, critical thinking and collaboration. This STEM approach has been championed by industry leaders because such educational programs are seen as good for developing the workforce of tomorrow by building young people's creative problem-solving capacities, as well as their technical design and engineering interests and skills.

In practise, designing and making in school contexts can be characterised as collaborative project work with concrete results (Heikkilä, Vuopala, & Leinonen, 2017). Many authors highlight that it is possible to integrate various subjects into design-driven projects, including art, crafts, technology, and science (Leponiemi, Virtanen & Rasinen, 2012; Tan & Peppler, 2015; Rolling, 2016).

In this chapter design-driven education is used as a pedagogical lens for seamless learning design, while twenty-first-century skills are presented in the context of design-driven education in Oulu's Fab Lab. Pedagogical design is first discussed from the perspective of seamless learning and will be addressed again in detail at the end of this chapter.

How is Seamless Learning Present in the Context of the Fab Lab Oulu?

Example 1: Fab4School, An Example of No Seamless Learning Design

Context and participants

Fab Lab Oulu, located in the University of Oulu in Finland, is a technology prototyping platform where learning, experimentation, innovation and invention are encouraged through curiosity, creativity, hands-on making and open knowledge sharing, similar to other Fab Labs around the globe. It is a space for university students, primary school pupils and other visitors to undertake studies or research-related projects, but it is also a space for the community around the university – namely, the citizens in the city of Oulu. The basic functions in Fab Lab Oulu are examples of making as entrepreneurship (as presented by Vossoughi & Bevan, 2014 – see introduction).

In addition to the global Fab Lab concept, there is a FabLab4School[1] project (a subdivision of Fab Lab Oulu) that aims to make Fab Lab activities known by all primary schools and high schools in the Oulu region. Specifically, it aims to get primary and secondary school pupils to become familiar with research and education in the field of technology and science at the University of Oulu. The main attractions of FabLab4School are 1) open doors to teachers and students on Fridays; 2) one-day workshops that aim of increase students' interest in Fab Lab activities; 3) longer-term projects, quite often consisting of multidisciplinary learning modules, and 4) summer schools.

A typical school visit to Fab Lab Oulu starts by discerning the preconditions for the students' future design activities. in the practice, context of the Fab Lab, materials and other possibilities are being presented to students by the instructors. Usually, there are three different templates for Fab Lab activities: 1) free design; 2) work on a given theme; or 3) realization of a concept which was started at the school. Pedagogical design of the FabLab4School activities is built around loosely-structured activities which are minimally guided. The main idea is to foster learning by doing, where a facilitator provides scaffolding only when needed and gives hints to solve a particular sub-problem of the bigger problem-solving process. Teachers of the visiting groups are important facilitators; their excellent knowledge of their own classes allow them to support students with maker activities.

How is seamless learning present in the design?

The FabLab4School programming is quite minimal from the point of view of seamless learning design. Because the roles of the home and school are not explicitly designed in the context of FabLab4School Oulu, seamless learning activities are dependent on the visitors: How are the pupils prepared? Do the individual visitors have personal interests in making, tinkering, coding or other relevant themes? When youngsters who have received a position in the summer school receive their confirmation letters, do they prepare themselves for their programmes? What are the post-visit activities? Do the students continue maker activities on a smaller scale in their school? In Figure 1 these questions are abstracted into visual form: pre- and post-activities are in dotted boxes because without explicit pedagogical design by the Fab Lab or the school there is no seamless learning (there are no explicitly designed activities which would integrate school, home and Fab Lab).

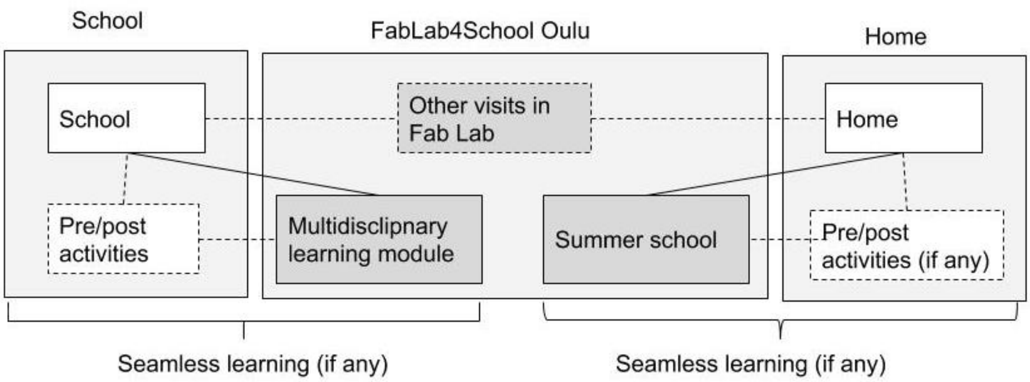

Figure 1. Fab Lab activities without a detailed seamless learning design

[1] http://fablab4school.fi/

Example 2: A Fully Seamless Learning Design

Example 2 is situated within a multidisciplinary learning module-project where activities have been divided between home, school and Fab Lab. What is particularly important in this example is that 1) the pedagogical design is created by students studying educational technology at a master's level in the university of Oulu and 2) these university students participate in maker activities with primary school pupils. (See next section in more details).

Context and participants

Participants in this study include 12 adult students from the Learning and Educational Technology (LET) master's programme in the University of Oulu, Finland, and 19 fifth-grade pupils (approx. 11 years old) selected from a public suburban elementary school (500 students) in the city of Oulu, in northern Finland.

The participating school has had two groups of pupils studying standard curriculum through hands-on maker activities in technology-oriented classes since 2014. The aim of that program is to increase technology (or digital) literacy, students' motivation, and twenty-first-century skills, such as creativity and problem-solving, by creating learning environments, which provide space and materials for students to learn and express innovation by building and experimenting with their own designs and solutions to open-ended, everyday problems. Maker and STEAM activities are built on four themes: 1) automation and robotics, 2) games and programming, 3) entrepreneurship and 4) product design and everyday technology.

LET's Research Unit has been offering postgraduate courses in Educational Technology studies for more than 20 years. The LET programme aims to develop the knowledge and competencies required in modern education – namely, skills for designing, conducting, assessing and analysing versatile learning situations, whether face-to-face or technologically enhanced. Moreover, many of the twenty-first-century skills that are required in today's working life are highlighted and supported in LET studies. Work/life connections are one essential feature of the LET programme.

Students in the LET programme participated in a ten-credit course, "Problem-solving case I" for two-and-a-half months. During the course, students learned how to apply theoretical knowledge to authentic educational challenges, how to design technology-enhanced learning activities in the makers education context, and how to work efficiently in a team to create a learning design. At the same time, students also participated in the eight-week, five-credit course, "Learning and Educational Technology." During the course students learned how to use digital tools to support learning and teaching as well as for programming and electronics. One week of the course design was reserved for exploring the possibilities of the Micro:bit platform, which was chosen to be used as a development kit in the school project.

How is seamless learning present in the design?

In this example, pedagogical design covers multiple learning contexts: university (including the faculty of education and Fab Lab), home and school. In addition to that, there were four different group of the actors in this example: university and school teachers, Fab Lab staff, LET master's programme students and primary school pupils. Masters' students had a task to design a pedagogical plan for the school pupils' project and also design a task to integrate into activities that they have designed.

This second example has many cross-contextual and cross-temporal trajectories for learning (cf. Looi, Seow, Zhang, So, Chen, & Wong, 2010). For example: masters' students had studied how to design an appropriate pedagogical model for design-driven learning – as well as how to use the Micro:bit development platform – in the context of maker activities for two months before the multidisciplinary learning module began. This temporal trajectory is visualised in Figure 2 in the form of a line with arrows in both ends.

The contextual trajectory is explicitly presented in the same figure, but with a horizontal arrow. This trajectory starts with students who tinkered with Micro:bit at home and did some background explorations with the available material about the design task. In addition to assigning the usual homework, classroom teachers also organized programming, measuring, technical drawing and electronics lessons before the multidisciplinary learning project began (see Figure 2).

After these preparatory activities, the multidisciplinary learning module launched in the school. This was a linear design project where face-to-face and online phases followed each other during the four-day span of the module. In the other words, a preliminary idea was incubated on the first day at the school and was transformed into a tangible product in the context of the Fab Lab over the following two days. From the seamless learning perspective, students ideas were "reified and practised in authentic settings" – in this case, in the Fab Lab – to "later be scrutinized, enriched, transformed and/or challenged within the social learning spaces [of the classroom/Fab Lab], among others with relevant but diversified personal perspectives, knowledge and experiences [i.e. master's students, grade-school pupils, and teachers from the university and school] mediating the socio-constructivist discourse" on issues such as collaboration in the classroom, online tools and Fab Lab (Wong, 2016).

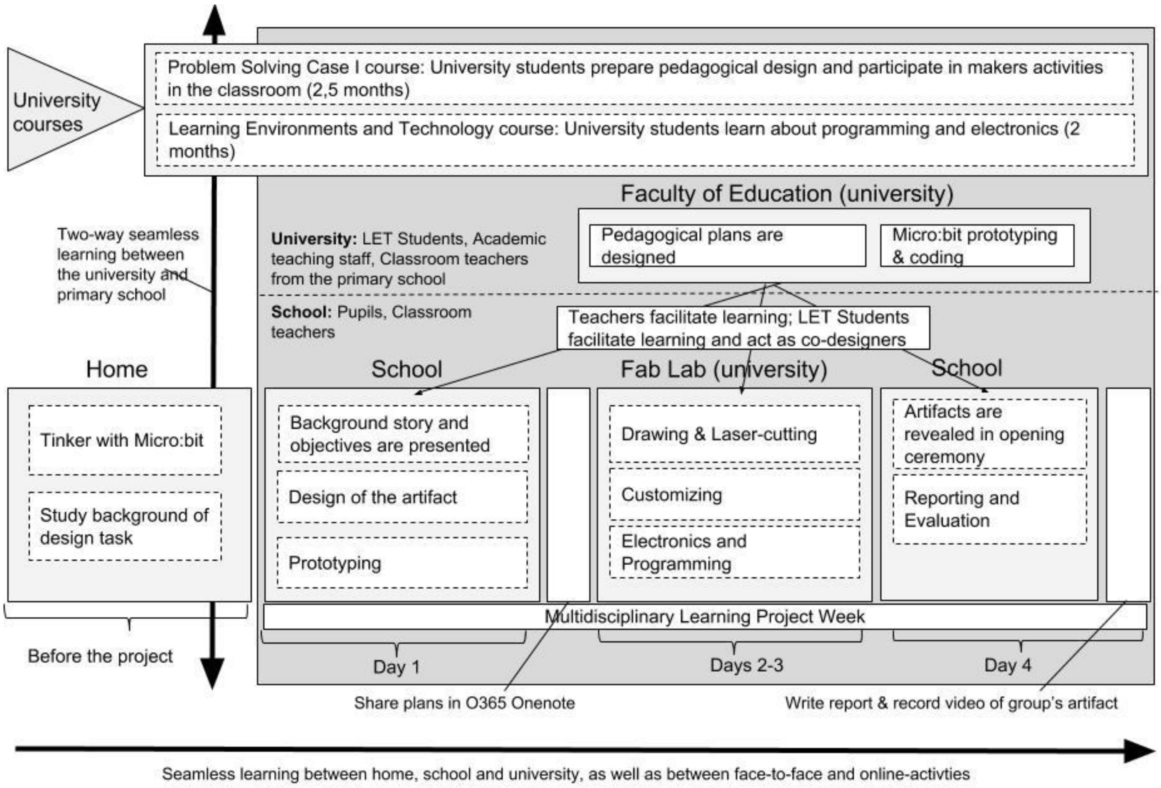

Figure 2. Temporal and contextual trajectories for seamless learning in the context of the second example

Detailed Description of a Pedagogical Model Using a Seamless Learning Approach: Education Master's Students and Primary School Pupils as Designers in Maker Activities

In line with the idea of design-driven education, LET students' work progressed through seven phases, all of which are described in Table 2. The first phase of design took place on the premises of the Faculty of Education and Fab Lab at the university. In this phase, LET students had one-and-a-half months to plan and test the pedagogical design for the multidisciplinary learning module and to learn how to program and use the Micro:bit development kit in collaboration with both university and primary school teachers (see Table 2). In this phase, co-designing took place between university students and teachers from the University of Oulu and Rajakylä school.

Table 2

Task Phases for Learning about Design-Driven Learning in the University Context (First Design Round for LET students, 1.5 months Duration)

Phases	Task for LET master's students, classroom teacher and university staff	Twenty-first-century skill(s)	Computational making /Computational thinking
Phase 1. Defining the problem	How do we implement design education in a classroom?	Critical thinking Creative problem-solving Collaboration	CM: Creativity, Understanding the materials CT: Connecting computing, Analysing problems and artifacts, Collaborating
Phase 2. Identifying the need	Why is it important to bring design thinking/ makers culture into primary school?	Critical thinking Creative problem-solving Collaboration Information literacy Life and career	CM: Creativity, Understanding the materials CT: Connecting computing, Analysing problems and artifacts, Collaborating
Phase 3. Collecting the information	What are some earlier cases about design-driven education in school contexts? What knowledge and skills do pupils need to master and what do they already master?	Creative problem-solving Learning to learn Collaboration Information literacy	CM: Creativity, Understanding the materials CT: Analysing problems and artifacts, Collaborating
Phase 4. Introducing alternative solutions	How can this project be implemented with pupils? What are the alternative solutions?	Critical thinking Creative problem-solving Communication Collaboration Information literacy ICT literacy	CM: Creativity, Understanding the materials CT: Developing computational artifacts, Analysing problems and artifacts, Communicating, Collaborating
Phase 5.	Which solution is the most	Critical thinking	CM: Aesthetics, Creativity,

Choosing the optimal solution	appropriate and why?	Creative problem-solving Collaboration	Understanding the materials CT: Analysing problems and artifacts, Collaborating
Phase 6. Designing and constructing a prototype and testing/piloting it	How do we construct the lesson plan in detail? How do we support school pupils with their programming and electronics activities?	Critical thinking Creative problem-solving Collaboration Information literacy ICT literacy	CM: Aesthetics, Creativity, Understanding the materials, Constructing CT: Developing computational artifacts, Analysing problems and artifacts, Communicating, Collaborating
Phase 7. Evaluation: Understanding what needs to be improved before implementation	What needs to be improved before the implementation?	Critical thinking Learning to learn Collaboration Communicating	CT: Analysing problems and artifacts, Communicating, Collaborating

The second phase of the activity was the implementation of the co-designed multidisciplinary learning module. Teachers, pupils and university students participated actively in the design and implementation of the project. The role of the teachers was to facilitate pupils' work while university students co-designed the problem-solution with primary school pupils (see Table 3 for detailed activities).

Table 3

Task Phases for the Pedagogical Design and Implementation (Second Design Round for LET Students and Learning Activity for School Pupils in the Primary School Context)

Day	Phases [physical setting]	Task [participants]	Twenty-first-century skill(s)	Computational making /Computational thinking
-1-3	Phase 0. Homework before project [home]	Practise basic programming with Micro:bit boards Research history of inventions and inventors Study how animals prepare for the winter [school pupils]	Critical thinking Information literacy ICT literacy Communication	CM: Understanding the materials, Constructing, Creativity CT: Connecting computing, Developing computational artifacts, Analysing problems and artifacts
1	Phase 1. Defining the problem, background story [school]	A class has a mascot but not a house for it, and the winter is coming. [LET students, school pupils]	Creative problem-solving Collaboration Communication	CT: Connecting computing, Collaborating
1	Phase 2. Identifying the need [school]	What do we have to do to get a house for the mascot? [LET students, school pupils]	Critical thinking Learning to learn Creative problem-solving	CM: Aesthetics, Creativity CT: Connecting computing, Analysing problems and artifacts,

			Collaboration Information literacy	Collaborating
1	Phase 3. Collecting the information [school, MS OneNote]	What requirements are there for the house? What materials do we need? What do we have to know, what skills do we have to master? [LET students, school pupils]	Learning to learn Creative problem-solving Collaboration Communication Information literacy ICT literacy	CM: Aesthetics, Creativity, Understanding the materials CT: Connecting computing, Analysing problems and artifacts, Communicating, Collaborating
1	Phase 4. Introducing alternative solutions [school, MS OneNote]	What alternatives do we have for a house? [LET students, school pupils]	Creative problem-solving Collaboration Communication Information literacy ICT literacy	CM: Visualising multiple representations CT: Developing computational artifacts, Analysing problems and artifacts, Communicating, Collaborating
2-3	Phase 5. Choosing the optimal solution [Fab Lab, MS OneNote]	Which alternative is the best one and why? [LET students, school pupils]	Critical thinking, Learning to learn Collaboration Communication Information literacy	CM: Aesthetics, Understanding the materials CT: Connecting computing, Analysing problems and artifacts, Communicating, Collaborating
2-3	Phase 6. Designing and constructing a prototype and testing/piloting it [Fab Lab]	How do we actually construct the house? [LET students, school pupils]	Creative problem-solving Critical thinking Collaboration Information literacy ICT literacy	CM: Aesthetics, Creativity, Constructing, Understanding the materials CT: Developing computational artifacts, Abstracting, Analysing problems and artifacts, Collaborating
2-3	Phase 7. Evaluation: Determining what needs to be improved before teacher's evaluation [Fab Lab]	What did we achieve? What should be improved? [LET students, school pupils]	Critical thinking Collaboration Information literacy ICT literacy	CM: Aesthetics, Understanding the materials CT: Analysing problems and artifacts, Collaborating
4	Phase 8: House opening ceremony, reporting and evaluation [School, Video, Padlet]	How do we present our house in the video clip? What do we write into our report? [LET students, school pupils]	Creative problem-solving Critical thinking Collaboration Communication Information literacy ICT literacy	CM: Creativity, Visualising multiple representations CT: Developing computational artifacts, Communicating, Collaborating

The students' primary task was to build a model house for a toy animal. These consists of several laser-cut plywood boxes, customised and furnished by students. Each pair of students make a plywood-box room and furnish it with crafts materials. After that the students build an electric system in the room. The third-grade students learn basic electronics by building an electric lightning system in the model house with recycled USB wires, LEDs and switches. The fifth graders are tasked with designing and building a home-automation application with Micro:bit development boards, servos, DC-motors, LEDs, etc. The Micro:bit boards are given to the students in advance so that they have time to get acquainted with their programming interface.

Conclusions

During this century, technological and methodological developments in information and communication technologies have changed the ways in which people communicate, collaborate and learn in fundamental ways. Ubiquitously present digital technology has changed our lives so that we are heavily influenced by computing - according to Barr and Stephenson (2011) today's students must begin to work with algorithmic problem-solving and computational methods and tools in K-12 schools.

It is not surprising that current generations of children and teenagers have generally good skills in using cognitive tools, such as computers, and smartphones and they are also quite familiar, for instance, with editing digital photos and creating web pages, but less than half of them can create something by exploration and fabrication technologies, such as do 3D designing, robotics or programming (Blikstein, Kabayadondo, Martin, & Fields, 2017).

However, Fab Labs are examples of engaging learning environments where participants "not only learn the target subject(s) but also come to understand the means for working with and creating knowledge (e.g. finding problems, re-presenting or remodeling knowledge, locating resources, testing ideas through experimentation" (Lam, Wong, Gayados, Huang, Seah et al., 2016, p. 1090). However, Papavlasopoulou et al. (2017) point out that "despite the interest in the Maker Movement and its connection to formal and informal education, there has been little research concerning the direction it is taking, the opportunities it could present for education, and why" (pp. 59).

While the original FabLab idea was conceived as a creative space for university students, and local inventors, nowadays there are a lot of networks, initiatives, and projects which aim to support collaboration and creative problem solving e.g. FabLearn Labs (USA), FabLab@School.dk (Danmark). The goal of some of the activities at the different digital fabrication networks is to engage children as quickly as possible in real projects, creating authentic context for learning. FabLab4school project in the context of Fab Lab Oulu is not expectation in that sense. However, carefully designed teacher preparation programs and pedagogical designs are still under the preparation. This contribution is one part of the process where visits of the primary and secondary school pupils into Fab Lab Oulu visits are being designed to be more integrated, more meaningful and more engaging.

From that point of view, seamless maker activities described in this chapter, illustrate practical implications for designing the use of multiple learning contexts, learning tasks, participant profiles and tools to support design driven education to teach twenty-first century skills, computational thinking and computational making in Makers contexts. Therefore, by providing an explicit socio-technical example, this chapter can contribute to pedagogical practices when educators are considering how they could integrate Fab Lab activities with their primary school lessons and curricula. Seamless approach for makers activities can be seen as a integration tool for Fab Lab facilitators, primary and secondary school teachers and academic teacher educators. Interplay between theoretical sections and examples of the pedagogical design in this chapter illustrate how complex ideas of computational thinking, design driven education and computational making can be integrated both into teacher education, primary school project and Fab Lab activities.

This case study was limited by the single-case design and the lack of empirical data collection and analysis. However, it also has been argued that research designs in the authentic contexts inevitably provide principles that can be localized for others to apply to new settings and to produce explanations of innovative practices (Fishman, Marx, Blumenfeld, Krajcik & Soloway, 2004). Therefore, research investigations conducted in authentic contexts are still needed as a first step to understand these new opportunities in terms of learning interactions and collaboration that seamless maker activities can produce.

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