# Implementing a Maker Culture in Elementary School - Students' Perspectives

Essi Vuopala, Diego Guzmán Medrano, Mariam Aljabaly, Dora Hietavirta, Lourdes Malacara Estrada & Chunxiao Pan

*Faculty of Education, University of Oulu, Finland*

Corresponding author: Essi Vuopala, PhD, is a university lecturer in the Learning and Educational Technology Research Unit (LET) in the Faculty of Education, University of Oulu, Finland. Her research interest deals with collaborative learning and technology-enhanced learning, especially from the viewpoint of social interaction and knowledge co-construction in higher education context. She is currently a lecturer in international Learning, Education, and Technology Master's Degree Programme.

Address: Faculty of Education, P.O. Box 2000 90014, University of Oulu, Finland. +358 40 5470778. Email: essi.vuopala@oulu.fi

Diego Guzmán Medrano, B.A, is a research assistant and a student in the Learning and Educational Technology Master´s Degree Programme in the Faculty of Education, University of Oulu, Finland. His background is in Elementary teaching. His research interests are constructionist approach in maker culture context and self-regulated learning (SRL).

Mariam Aljabaly is a student in the Learning, Education and Technology master's degree International Programme in the Faculty of Education, University of Oulu, Finland. Her background is in English language teaching.  Her research interest is in technology-enhanced learning and collaborative learning in both primary and higher education context.

Dóra Hietavirta, BA in Community Learning and Development, is a student in the Learning, Education and Technology Master's Degree Programme in the Faculty of Education, University of Oulu, Finland. Her research interest is in software and interaction design for collaborative learning, and system design regarding alternative compulsory education.

Lourdes Malacara Estrada, BA of Science in Education, is a student in the Learning, Education and Technology Master's Degree Programme in the Faculty of Education, University of Oulu, Finland. Her

research interest deals with STEM education, technology-enhanced learning and professional development of STEM educators.

Chunxiao Pan is a student in Learning, Education and Technology Master's Degree Program in the Faculty of Education, University of Oulu, Finland. She is interested in the research of technology-enhanced learning, language learning and teaching, and collaborative learning.

# Implementing a Maker Culture in Elementary School - Students' Perspectives

This study investigated students' perspectives on working and studying within a maker culture context. Participants were 5th-grade students (n = 18) in a Finnish elementary school who worked on a fabrication project for 5 days. The data consisted of student questionnaires (n = 18), group presentations (n = 5), and the final fabrication products (n = 5). The findings indicate that students were satisfied with their maker projects in terms of their own contribution as well as their group's work. Students reported that they learnt various skills, including technical skills, English language and study skills. Although digital fabrication was emphasized in the project, students mostly fabricated the elements for their final product using traditional fabrication methods. The findings from this study can be helpful for designing effective maker projects in primary education settings.

Keywords: maker culture; digital fabrication; design-driven education; 21st-century skills, elementary school

## Introduction

There is a growing interest worldwide in revolutionizing education. A variety of new ideas have taken shape and been adopted in attempts to transform the way we learn and teach in schools, thus making education better suited to our current reality. One of the latest concepts that has been seeping into the everyday lives of teachers and students is the maker culture idea (Blikstein, 2013; Blikstein, 2018). A maker culture refers to a context where individuals or groups produce digital and/or tangible objects and, at the same time, engage in the design process when planning, testing, implementing and assessing different solutions for the problem at hand. (Papavlasopoulou, Giannakos, & Jaccheri, 2017).

Students at all levels of education need to master a variety of skills required in the 21st century, including problem solving, productive participation in teamwork, use of information- and communication technology (ICT) and computational skills (Häkkinen et al., 2017; Krokfors et al., 2011). One way to support the development of students' 21st-century skills is to engage them in maker culture activities and to provide them with opportunities to creatively solve open-ended problems together (Bekker, Bakker, Douma, Poel, & Scheltenaar, 2015; Blikstein, 2013; Pucci & Mulder, 2015).

Although the maker culture has its root in learning by doing and constructivism, nowadays it includes digital fabrication, where various technological devices and software, physical computing and programming are used for solving complex problems (Papavlasopoulou et al., 2017). And while the maker culture approach was traditionally used only in the field of computer science, it has recently been recognized as also having value in the field of education (e.g., Heikkilä, Vuopala, & Leinonen, 2017). In Finland, the national curriculum highlights learning by doing, collaborative learning, project-based learning and phenomena-based learning, and all these ideas can be put in practice in the context of a maker culture.

In recent years, there has been a growing number of empirical studies related to a maker culture in K-12 education (e.g., Blikstein, 2013; Halverson & Sheridan, 2014; Heikkilä et al., 2017; Papavlasopoulou et al., 2017; Vossoughi & Bevan, 2014). In these studies, both learners' (e.g., Sheridan et al., 2014) and teachers' (e.g., Heikkilä et al., 2017) perspectives have been taken into account. Although in these studies the duration and type (solo, peer or collaborative) of various maker projects in educational context varied, similar type of learning outcomes were reported. Students participating in maker culture activities learnt mainly about fabrication processes (Chu, Angello, Saenz, & Quek, 2017) and gained technical skills as well as study skills like reflection, debate, teamwork and problem solving (Galaleldin, Bouchard, Anis, & Lague, 2016; Sheridan et al., 2014). In addition, studies have reported increased interest and confidence towards technology use when engaging in maker activities in elementary school context (Eriksson, Heath, Ljungstrand, & Parnes, 2018; Holbert, 2016).

Freedom and creativity were found to be the main motivators for students to engage in maker activities (Smith, Iversen, & Hjorth, 2015; Somanath, Morrison, Hughes, Sharlin, & Sousa, 2016). It has also been reported that, in general, students enjoy studying and working in the maker culture context (Chu, Angello, Saenz, & Quek, 2017; Posch & Fitzpatrick, 2012; Sheffield, Koul, Blackley, & Maynard, 2017), especially when the maker projects has been loosely structured and the students are given a freedom to choose the projects they want to implement (Bar-El & Zuckerman, 2016; Bekker, & al., 2015; Schwartz, DiGiacomo, & Gutierrez, 2013). Also, working in groups within a maker project has been reported to be enjoyable for students (Blackley, Rahmawati, Fitriani, Sheffield, & Koul, 2018). However, as highlighted in the study by Smith, Iversen and Hjorth (2015), it is essential that a teacher frames a design challenge well or the learners may lose interests and motivation, which in turn might weaken their engagement.

Although there has been a growing interest in implementing the maker culture idea in educational settings, there is a lack of empirical research focusing on the possibilities and authentic experiences of implementing a maker culture in formal education (Papavlasopoulou et al., 2017). Therefore the aim of this study was to provide insight regarding students' perspectives of working and learning with a group in the context of a maker culture. Our specific research questions were the following:

(1) How did the students assess their own and their groups' work during the project?

(2) What content did the students perceived that they learnt during the project?

(3) What elements did the final fabrication products included?

## Background

### *Learning by making*

The idea of a maker culture has been around for a long time, and the affordances of the maker culture to learning are multifold (Blikstein, 2018). Having its theoretical origins in Papert's constructionism, Dewey's experiential education and even Freire's critical pedagogy, it places the learner firmly at the centre of the learning process with a focus on the connection to real-world issues and meaningful problems. However, as the focus in formal education shifted towards content acquisition in the latter half of the past century, making and creating were relegated to hobbies or extracurricular activities. In addition, the rapid expansion of affordable digital tools has diminished the importance of physical creation even further.

Despite these changes in modern society, learning scientists have rediscovered the maker culture concept as having benefits for academic learning (Halverson & Sheridan, 2014). They have found that when engaging in maker culture activities, students develop a sense of personal agency, improve their self-efficacy and self-esteem and become members of a community (Chu, Schlegel, & Quek, 2017; Halverson & Sheridan, 2014). Therefore, the experience of learning through making can be empowering and can nurture students' creativity and inventiveness among other 21st-century skills (Blikstein, 2013). Maker activities can be applied for multiple learning purposes including various aspects of science, technology, engineering and mathematics (STEM) (e.g. Chu, Angello, Saenz, & Quek, 2017; Davidson & Price, 2017; Marsh, Arnseth, & Kumpulainen, 2018; Posch & Fitzpatrick, 2012). Thus, educators are looking into possible ways of promoting a maker mindset, not by turning away from digital technology, but by incorporating the use of digital media to enhance learning (Halverson & Sheridan, 2014). One way to engage learners in maker culture activities is through a design-based approach (Bekker et al., 2015).

### *The role of design-driven education*

Design-driven education can be defined as learner-centred project work in which the students have an active role in every phase of the learning process, including planning, execution and evaluation (Nelson & Stolterman, 2003). The idea of design-driven education also includes students and teachers collaborating together throughout the process. The teacher's role is to support and guide the students and to encourage them to collaborate in order to find relevant and innovative solutions to a task (Bekker et al., 2015). Furthermore, the idea of design-driven education emphasizes the role of the students' own expertise and interests as well as importance of integrating outside experts into the learning process (Bekker et al., 2015; Seitamaa-Hakkarainen, 2011).

The design process starts with the realization that there is a disparity between our current and desired states and that bringing about a transformation requires intentional effort and actions. To produce solutions to complex societal problems one needs to have a specific skill set that includes the so-called 21st-century skills: creative and critical thinking, logical reasoning, problem solving, systems thinking, communication and collaboration. And by giving students opportunities to engage in design processes, experiment with design methods and approach problems with a focus on finding solutions, schools can prepare them to face a wide variety of problems, deal with difficult situations, think outside the box and generate innovative ideas not just within the school setting, but also later in life (Nelson & Stolterman, 2003).

In the context of elementary education, maker projects have often been implemented as design workshops, with open tasks and loose instructions following the phases of design process:

brainstorming possible solutions, building prototypes, fabrication and evaluation (Bar-El & Zuckerman, 2016; Bekker & al., 2015; Bers, Strawhacker, & Vizner, 2018; Blackley et al., 2018; Holbert, 2016; Schwartz, 2013). In these projects, students typically work with peers (Chu, Angello, Saenz, & Quek, 2017) or in small groups (Blackley et al., 2018; Sheffield et al., 2017), while teacher's role is to be a facilitator or a mentor who instructs the students when necessary and maintain their motivation (Chu, Angello, Saenz, & Quek, 2017; Sheffield et al., 2017).

### *Digital technology and programming in maker culture*

The presence of technological advances in everyday life is transforming the world, including the educational field. Therefore, the use of various technologies is a natural part of solving problems within a modern maker culture (Blikstein, 2013). However, technology needs to be supported by a learning environment that fosters a constructionist approach (Katterfeldt, Dittert, & Schelhowe, 2015) and in which learners can engage in hands-on tangible actions (Goodyear & Retalis, 2010). As a result, the use of technological devices that blend the physical and the digital worlds has become popular. The design and creation of 'tangible interactive objects or systems using programmable hardware' (Przybylla & Romeike, 2014, p. 2), such as minicomputers or microcontrollers, is known as physical computing and is one on the key learning skills in the 21st-century. For example, learners can code a handheld programmable computer using a language such as JavaScript to connect it with sensors and servos to open a door, make lights blink or even create more complex outcomes.

In physical computing, the aim is to promote the development of creative ideas and products rather than technical knowledge about technology (Blikstein, 2013). Learners start with a vision of their object and its interaction with the environment (Przybylla & Romeike, 2014) and then select the software and hardware, develop a prototype and test their results. Learners can receive immediate feedback while testing, and make adjustments if necessary, as they have the control of the object (Katterfeldt et al., 2015). The BBC micro:bit is an example of a pocket-sized codable physical computing device (Sentance, Waite, Hodges, MacLeod, & Yeomans, 2017) that allows learning through construction. Its main purpose is the use digital technologies in creative ways to foster science, engineering and technology skills. Micro:bit stimulates and supports understanding due to its tangibility.

Sentance et al. (2017) stressed that with a constructionist approach, micro:bit can provide a compelling first exposure into coding, digital technology and computational thinking for learners of all ages. Combined with the current maker culture that fosters curiosity and motivation, students can learn about how programming can help them create solutions for real situations. Thus, instead of perceiving themselves as merely consumers, they can see themselves become producers of tangible products emerging from their own imagination (Katterfeldt et al., 2015).

### *Collaborative learning*

In addition to physical computing and ICT skills due to the technological advancements of the last few decades, collaborative learning is receiving increased attention in the educational context and is considered one of the essential 21st-century skills (e.g., Häkkinen et al., 2017; Volet, Vauras, Salo, & Khosa, 2017). Collaborative learning refers to situations in which learners work in groups to complete a common task and construct knowledge jointly through social interactions (Dillenbourg, 1999). The goal of collaborative learning is to develop learners' understanding and to construct new knowledge through social interactions (Janssen, Erkens, Kirschner, & Kanselaar, 2009). Individual learning outcomes depend on how individuals' commit to collaborative activities like argumentation, explaining and asking questions which enhance their understanding (Dillenbourg, 1999). One way to promote collaborative learning is to engage learners in joint maker activities where learners' are required to negotiate about common tasks, share their expertise, and monitor the progress (Lockhorst, Admiraal, & Pilot, 2010; Stager, 2013). It is generally recognized that collaborative learning enhances critical thinking, conceptual thinking and communicating skills. Effective and efficient collaborative learning can occur in a problem-solving learning situation (Kirschner, Paas, Kirschner, & Janssen, 2011), when individuals are put together to solve a complex task and where everybody's contribution is needed and acknowledged. Collaborative learning, such as group work, team effort and on-time feedback from instructors, has been found to have a positive effect on learning outcomes and to enhance the learning experience (Inayat, Amin, Inayat, & Salim, 2013).

As we can see, both design-driven education and the maker culture, including digital fabrication and collaborative learning, can have a positive influence on learning in schools. Smith et al. (2015) emphasize the need to combine these two approaches for maximum impact and to create a 'hybrid' learning environment in which various aspects of design-driven education and the maker culture is taken into account. In this study, we therefore designed this kind of hybrid environment, described below, and studied students' views of their learning within a maker culture context.

## Methodology

### *Context and participants*

This empirical research was implemented as a small-scale case study focusing on a specific, short-term event to analyse participants' perceptions of their learning in a class context (Cohen, Jones, Smith, & Calandra, 2017). In this study, a case is defined according to Yin (2002) as a contemporary phenomenon in a real life context, and case study as an empirical inquiry that examines the case by addressing the ‘how’ question concerning the phenomenon. The purpose of the case study approach is to present an authentic and interesting case to audiences, and the nature of research is descriptive. Case study methods fits well into learning science research because of its holistic approach. Through a case study the phenomena can be understood deeply from the participants’ point of view.

In this study, the starting point was to gather feedback from elementary school students concerning a group project in the context of a maker culture. The study was implemented in a Finnish elementary school located in the northern region of the country with two technology-focused classes during the 2017-2018 academic year – one class of third graders and one of fifth graders. These classes provide space, time and materials for students to work with their hands, using creativity and design artefacts from everyday life. The school has several facilities which support different kinds of fabrication projects, such as 3D printers, laser cutters, milling machines and computers. As part of their normal school days, the students carry out technology projects focused on everyday topics. Collaboration with local companies, national projects and the University of Oulu provides a context for these projects.

The fifth graders implemented a digital fabrication project both in school and at the FabLab at the University of Oulu. FabLab provides several options for both digital and traditional fabrication, an ideal space and facilities to implement the maker culture idea. FabLab was originally founded at the Massachusetts Institute of Technology by professor Neil Gershenfeld in 2003, and since that time the concept has spread all over the world. Basically, FabLab is an open space for different kinds of fabrication projects. It provides a variety of equipment, including laser cutters, 3D printers and computer-controlled milling machines, as well as software for programming and sketching. In additional, it equipped with tools for traditional fabrication, such as sewing machines, saws, scissors, screwdrivers and so on. All FabLabs are interconnected, and a product that has been fabricated in one FabLab can be replicated in another (Gershenfeld, 2012).

The duration of the project was five days, and on each day the students worked for 5 hours. The task was to design a house for the class mascot “Masa”, a miniature dinosaur. The teacher gave the following collaborative task to the students: “Masa is our mascot who lives in northern Finland. In the winter it is very cold and Masa does not have any warm place to stay overnight. So he needs a house. Your task is to design and build him one. Each small group will build one room, and finally all rooms will be put together”. The students were directed to follow the design process (see Figure 1), and each group planned and constructed one room for the house (which were then all put together for the final fabrication product). Groups negotiated and decided by themselves which room they wanted to build, and in the end the house included a disco, a sauna, a doctor’s room, an office, and a bedroom. Students used micro:bits for the home electronics (e.g., LED lights and a fan), 3D printers for the furniture, a laser cutter for the walls and for some furniture and clay and fabric for the furniture.

[Figure 1 near here]

The students (n = 18, 12 males and 6 females) were divided into five small groups by the teacher. Each group had their own facilitator, who was a university student in the field of education and technology. The facilitator’s role was to script the design process and support students’ collaboration during the project. In general, the script was quite loose and provided a lot of freedom for the students to design their own projects. Altogether there were three phases in the project: the planning phase, the application phase, and the evaluation (presentation) phase.

The planning phase occurred in school on the first day. The students planned the type of the room they wanted for their mascot, furniture and other elements they wanted to include into the room, skills and technologies they needed to fabricate the room and the materials they would need. The students also divided up roles and responsibilities; for example, one group member was responsible for coding the micro:bit, one for interior design and one for cutting pieces for the room. However, they were encouraged throughout the process by their facilitators to collaborate in different phases of the design process.

The second and third day comprised the application phase, when the students started turning their design into reality in FabLab. Each small group picked the materials (acrylic or plywood) that their room would be made of and took turns using the laser cutter and cut out the pieces for their room. Then each group started to assemble their room, and some of the students started to shape some parts of the furniture with clay, foam, or wood. Additional materials were brought from the school including fabric, stones and micro:bits.

After designing and creating about 90 percent of their room, the students returned to their classes to complete their work on the fourth day. The presentation phase was on the fifth day, when the students planned and created PowerPoint presentations and put the final touches on their rooms. The final presentations included a reflection of the project (i.e., what we learned, how we worked, how the work was divided and what materials we used) and a video introducing how Masa spends his day in their room.

### *Data collection and analysis*

The primary empirical data of this research consisted of student questionnaires (n = 18; see Appendix 1) with both Likert-scale and open-ended questions and the final fabrication products, i.e., the rooms for Masa, the mascot (n = 5). Additional data consisted of the final group presentations (n = 5). According to the case study method both qualitative and quantitative analysis methods were applied (Yin, 2002). A qualitative, data-driven content analysis (Chi, 1997) was used to analyse the students' responses to the open-ended question "What did I learn from this project?" in the questionnaire data and the final group presentations. Descriptive statistics (i.e., frequencies and mean values) were used in the analysis of the Likert-scale questions and final fabrication products as well as to quantify the results of the qualitative content analysis.

In practise, related to Research Questions 1 and 2, the qualitative content analysis of the questionnaires (open-ended question "What did I learn from this project?") and group presentations (open-ended question "What did we learn?") proceeded through four phases. First, the unit of analysis related to each research question was separated from the data. The unit of analysis was either one or more sentences, each including one meaning within them. While the fifth graders typically wrote only short answers with one or two sentences, the unit of analysis was one answer. In the second phase, the preliminary coding scheme was formulated, and each unit of analysis was placed in one of these categories. In the third phase, the coding scheme was tested and then reformulated. Finally, the number of codings per each category was calculated. The coding scheme is presented in Table 1.

[Table 1 near here]

Related to Research Question 1, the answers to the open-ended question, "How did I feel during the project? Why?" were categorized as very positive (i.e., "Very good since it was fun"), quite positive ("I felt semi-okay") or mixed ("It was fun and hard") depending what kinds of feelings students expressed in their answers.

The analysis of the final fabrication products proceeded through three phases (Research Question 3). First, all elements each room included were listed, and secondly, categories describing these elements were formulated. Categories were micro:bit-related elements, 3D-printed elements, laser-cut elements and elements fabricated as traditional handicrafts (i.e., cutting, formulating clay, sewing, etc.). Thirdly, all the elements were allocated into one of the categories. Finally, the total number of elements per category was calculated. The coding scheme is presented in Table 2.

[Table 2 near here]

## Results

### *How did the students assess their own and their groups' work during the project?*

Based on the analysis of the questionnaires, we can conclude that the students mostly felt that they participated actively and productively in the group work (see Table 3). All the students (n = 18) agreed with the statement "I contributed useful ideas". In addition, almost all students (17 out of 18) agreed that they participated in the group activities and that they listened to others in their group. Also, most of the students (16 out of 18) agreed they completed their work on time. The number of the students who agreed with the statement 'I helped others in the group' accounted for 15 out of 18, which means that only 3 students disagreed with this statement. In conclusion, most of the students chose a smiley face or a big smiley face for these statements and were pleased about their individual work in their groups. However, in the open-ended questions, 5 students stated that they needed to improve their group work skills in order to better participate in the project work.

[Table 3 near here]

Also, according to the results of the analysis of questionnaires, students were also mostly satisfied with the group work; they strongly felt that they had done an excellent job on the project and were satisfied with the outcome (Table 4). The students assessed their group work even more positively than their individual participation and contribution (more "totally agree" responses). All the students agreed that they completed their group work on time, with 15 students "totally agree" and the remaining "agree". Besides, 17 students agreed with the other four statements: "We did an excellent job", "We worked together", "We helped each other" and "We shared and listened to each other's ideas". To conclude, most of the students held the opinion that their collaboration and cooperation in their groups were satisfactory.

[Table 4 near here]

In addition, most of the students (15 out of 18) expressed positive feelings towards studying in the maker culture context: "It was fun and nice to do this project", "This was so funny and easy" and "I feel good because we finished our project". Two students expressed that working on the project was "semi-nice" or "quite ok". Also, two students expressed mixed feelings towards the project: "Because sometimes there were feelings of success and failure, sometimes I was frustrated because something didn't work" and "It was fun and hard to make, but with teammates we did it fast".

***What content did the students perceived that they learnt during the project?***

As illustrated in Figure 2, all the students (n = 18) expressed that they learnt about programming or other technical skills like using Tinkercad, as the following quotes illustrates: "I learnt how to code a rainbow micro:bit" and "I learnt to make LEDs and code micro:bit". In addition, the students described that during the project they increased their English language skills (f = 5; "I now know more English") and also improved their study skills (f = 3; "I learnt group work").

Only two students mentioned that they learnt nothing or couldn't express what they did learn during the project.

[Figure 2 near here]

When looking at the group presentations, the findings were similar compared to the questionnaires except in their presentations students emphasized various technical skills as their main learning outcomes: "We learnt more about using Tinkercad and more about 3D printing. We also learnt a little bit of Spanish and English" (Group 3). In almost all (4 out of 5) group presentations, the use of micro:bit was mentioned as a learning outcome. Other skills mentioned were Tinkercad and 3D printing (2 out of 5), laser cutting (2 out of 5) and traditional handicrafts (2 out of 5). Also, in two presentations improved English language skills were mentioned.

***What elements did the final fabrication products include?***

Although this project was mostly a digital fabrication project, 'traditional handicrafts' were primarily used (see Figure 3). Traditional handicrafts refers here to using a sewing machine, sawing, cutting, gluing, etc. In all five rooms, 31 elements were fabricated 'traditionally', including curtains, carpets, miniature books, pillows, blankets, sofas and paintings. Four rooms included some laser-cut elements (f = 14), such as for the walls for the house and furniture. Also, four rooms included some digital objects coded with micro:bit (f = 7). These objects were mostly LED lights. Four groups also had some 3D-printed elements, like a TV, printer and some furniture, in their rooms (f = 5).

[Figure 3 near here]

As can be seen, there were two rooms in which both digitally fabricated (micro:bit, 3D-printed and laser-cut elements) and traditionally handcrafted elements were included. In three rooms, there were three different types of elements. As mentioned earlier, the common feature of all five rooms was that traditionally produced elements had a main role. Picture 1 illustrates a room that included all four types of elements: laser-cut wooden walls and a shelf, micro:bit-coded LED lights on the ceiling, a 3D-printed TV and screen on the table, printed paper magazines on the shelf and a sofa and carpet cut out with scissors.

[Picture 1 near here]

**Discussion**

The purpose of this study was to investigate elementary-aged students' perceptions of their learning and studying in the context of a maker culture. The main results indicate that the students were satisfied with their projects in terms of their own participation and contribution as well as their group's work. They also expressed positive feelings towards the project. In other words, students found the maker approach to learning enjoyable. These findings correspond with findings from earlier studies (e.g., Posch & Fitzpatrick, 2012; Sheridan & al., 2014) which claim that young students generally find pleasure and hold positive attitudes with being involved with maker activities, as these provide different kinds of learning experiences that are novel and exciting compared to their usual school day environment. Sheridan and colleagues (2014) concluded that working in multidisciplinary makerspaces can fuel engagement and innovation, and the findings of our study also confirm this statement.

Our findings are also in line with earlier studies (Chu, Quek, Bhangaonkar, Ging, & Sridharamurthy, 2015; Posch & Fitzpatrick, 2012) through the demonstration that the students learnt various skills while participating in maker activities. In our study, students reported that they mainly learnt technical skills, including programming, but also English language skills and study skills. It can therefore be concluded that the students' awareness about technology, maker culture and programming was increased, which is in accordance with the findings from Chu and colleagues (2015) and Posch and Fitzpatrick (2012), who found that maker activities improve learners’ awareness of the potential and challenges of technology. However, in the studies by Chu and colleagues (2015) and Somanath et al. (2016), soft skills like collaboration were highlighted as main learning outcomes, while in our study technical skills were mostly emphasized.

The framing of the design challenge was based on an agreement between the teacher and the students that the class mascot needed accommodation before the change of seasons. While this decision making did not allow the students to do research freely to discover existing needs they could have addressed through designing, the students did have a high degree of freedom within the overall challenge. Analysis about how things could be done better was ongoing in terms of appropriate material or technology use, or regarding the rescaling or replacing of items as well as the allocation of tasks within teams.

Although digital fabrication was emphasized in our project, students mostly fabricated the elements for their final fabrication product using traditional fabrication methods such as sewing, cutting with scissors and gluing. One reason for this might be that these traditional methods are more familiar and therefore ‘safer’ to the students as reported by Somanath et al. (2016), who found that the use of common materials and art supplies creates an appropriate comfort level in maker activities for students who feel particularly intimidated by electronic components and who prefer, as a starting point, to prototype and build something with more familiar materials.

As for the nature of this project, the students were confronted with a design challenge that was practical and based on a real-world object (the mascot’s house). This fact helped them contextualize the problem and encouraged them to explore different materials and their own interests as suggested by Smith et al. (2015) and Somanath et al. (2016). Task formulation as well as the availability of versatile materials are key factors in engaging students in maker activities.

According to the reflection and feedback from the students, the project considerably engaged the students in maker culture activities in the learning environments of school and the FabLab. The project involved the learners working out their ideas by using their hands and other devices, which is in alignment with the idea of learning by doing. We can affirm that this experience led to an improvement in the students' traditional handicraft skills; a deeper knowledge of modern fabrication machines, such as 3D printers and laser cutters, and electronics; and also insight in computational thinking. Moreover, the finished products reflected the students' independence regarding the division of labour and in organising their own work. In this fashion, based on the elements included in the rooms, the students completed the process of successfully designing a product and merging it with electronic gadgets to make a functional room. In addition, most of the students were satisfied with and positive about the rooms they designed and the final presentations they made.

## Conclusions

This study contributes to the current discussion concerning applying the idea of maker culture in school context, and provides a successful example of collaboration among teachers and pupils of a primary school, students and teachers from the university, and staff at FabLab. It encourages people with various expertise to be involved in the implementation of a multidisciplinary maker project.

This study has practical implications for the fields of both primary and teacher education. The results of this study can encourage teachers in primary education to integrate the idea of a maker culture into everyday school activities since it can promote student engagement and make learning enjoyable. While being an effective way to enhance students' technical skills, maker activities can also have a positive effect on students learning skills such as collaboration and communication skills.

Since fabrication projects in the context of a maker culture require careful task formulation and teacher facilitation throughout the process, it is essential that future teachers are equipped with 21st-century skills during their own education. Teacher training institutions should be prepared to train their students on how to make use of the affordances that maker spaces provide for learning. As learning is taking a more and more multidisciplinary approach, there is a need for prospective teachers to understand what skills they themselves need to possess to successfully integrate maker activities into their teaching repertoire, including knowledge about technology, collaborative problem solving, and design and other creative processes.

The strength of this study is that it provides an authentic example of learning and studying in a maker culture context. This intensive multidisciplinary project combined both digital fabrication and traditional handicraft. It included textile work, programming, digital software, English language, and shed light on how to design projects that are well-structured and also leave autonomy for learners to explore, to design, and to create.

This study has certain limitations, such as its small sample size. Although no generalizations can be made based on the present data, this study contributes research findings related to maker space by presenting evidence from a real-life learning situation within a maker culture from the students' own point of view. In addition, time constraints caused some challenges for the data collection. Also, some small groups progressed more slowly than others, and they did not have time to complete the reflection task at the end of each work session and to write the progress report for the final presentation. Mostly the small groups reflected on the process at the end of the project. However, the work periods were intense, and the students were able to clearly remember the process and their progress at the end of the 5-day period.

In our future research, we will focus on knowledge co-construction within a maker culture. In formal education it is important to understand how people learn collaboratively while engaging together in maker activities. While this study evidenced that students did learn various contents and skills, it stayed unclear *how* they learnt while collaborating, and the aspect of productive interactions (see Vuopala, Näykki, Isohätälä, & Järvelä, 2019) during collaborative learning will be in the focus of our upcoming research.

## References


Bar-El, D., & Zuckerman, O. (2016). Maketec: A Makerspace as a Third Place for Children. *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, 380–385. https://doi.org/10.1145/2839462.2856556

Bekker, T., Bakker, S., Douma, I., Poel, J. Van Der, & Scheltenaar, K. (2015). Teaching children digital literacy through design-based learning with digital toolkits in schools. *International Journal of Child-Computer Interaction,* 5, 29–38. https://doi.org/10.1016/j.ijcci.2015.12.001

Bers, M. U., Strawhacker, A., & Vizner, M. (2018). The design of early childhood makerspaces to support positive technological development: Two case studies. *Library Hi Tech*, *36*(1), 75-96. https://doi.org/10.1108/LHT-06-2017-0112

Blackley, S., Rahmawati, Y., Fitriani, E., Sheffield, R. & Koul, R. (2018). Using a makerspace approach to engage Indonesian primary students with STEM. *Issues in Educational Research*, 28(1), 18-42. http://dx.doi.org/10.1016/j.tate.2013.04.001

Blikstein, P. (2013). Digital fabrication and 'making' in education: The democratization of invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLabs: Of machines, makers and inventors* (pp. 203-222). Transcript Publishers.

Blikstein, P. (2018). Maker Movement in Education: History and Prospects. In M. J. de Vries (Ed.), *Handbook of Technology Education* (pp. 419–437). https://doi.org/10.1007/978-3-319-44687-5_33

Chi, M. T. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences*, 6(3), 271-315. https://doi.org/10.1207/s15327809jls0603_1

Chu, S. L., Angello, G., Saenz, M., & Quek, F. (2017). Fun in making: Understanding the experience of fun and learning through curriculum-based making in the elementary school classroom. *Entertainment Computing*, 18, 31-40. https://doi.org/10.1016/j.entcom.2016.08.007

Chu, S. L., Quek, F., Bhangaonkar, S., Ging, A. B., & Sridharamurthy, K. (2015). Making the maker: A means-to-an-ends approach to nurturing the maker mindset in elementary-aged children. *International Journal of Child-Computer Interaction*, 5, 11-19. https://doi.org/10.1016/j.ijcci.2015.08

Chu, S. L., Schlegel, R., & Quek, F. (2017). ‘I Make, Therefore I Am’: The Effects of Curriculum- Aligned Making on Children's Self-Identity. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 109–120.

Cohen, J., Jones, W. M., Smith, S., & Calandra, B. (2017). Makification: Towards a framework for leveraging the maker movement in formal education. *Journal of Educational Multimedia and Hypermedia*, 26(3), 217-229.

Davidson, A.-L. and Price, D. (2017). Does Your School Have the Maker Fever? – An Experiential Learning Approach to Developing Maker Competencies. *LEARNing Landscapes*, 11(1), 103-120. https://www.learninglandscapes.ca/index.php/learnland/article/view/926

Dillenbourg, P. (1999). *Collaborative learning: Cognitive and computational approaches*. Amsterdam: Pergamon, Elsevier Science.

Eriksson, E., Heath, C., Ljungstrand, P., & Parnes, P. (2018). Makerspace in school: considerations from a large-scale national testbed. *International Journal of Child - Computer Interaction*, 16, 9-15. https://doi.org/10.1016/j.ijcci.2017.10.001

Galaleldin, M., Bouchard, F., Anis, H., & Lague, C. (2016). The impact of makerspaces on engineering education. *Proceedings of the Canadian Engineering Education Association (CEEA).*

Gershenfeld, N. (2012). How to make almost anything: The digital fabrication revolution. *Foreign Affairs*, 91(6), 43-57.

Goodyear, P., & Retalis, S. (2010). Learning, technology and design. In P. Goodyear & S. Retalis (Eds.), *Technology-enhanced learning: Design patterns and pattern languages* (pp. 1-28). Sense Publishers.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing teacher-students for twenty-first-century learning practices (PREP 21): A framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching: Theory and Practice*, 23(1), 25-41. https://doi.org/10.1080/13540602.2016.1203772

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 495-504. https://doi.org/10.17763/haer.84.4.34j1g68140382063

Heikkilä, A-S., Vuopala, E., & Leinonen, T. (2017). Design-driven education in primary and secondary school contexts. *Technology, Pedagogy and Education*, 26(4), 471-483. https://doi.org/10.1080/1475939X.2017.1322529

Holbert, N. (2016). Bots for Tots: Building Inclusive Makerspaces by Leveraging Ways of Knowing. *Proceedings of the The 15th International Conference on Interaction Design and Children*, 79-88. https://doi.org/10.1145/2930674.2930718

Inayat, I., ul Amin, R., Inayat, Z., & Salim, S. S. (2013). Effects of collaborative web based vocational education and training (VET) on learning outcomes. *Computers & Education*, 68, 153-166. https://doi.org/10.1016/j.compedu.2013.04.027

Janssen, J., Erkens, G., Kirschner, P., & Kanselaar, K. (2009). Influence of group member familiarity on online collaborative learning. *Computers in Human Behavior*, 25(1), 161-170. https://doi.org/10.1016/j.chb.2008.08.010

Katterfeldt, E., Dittert, N., & Schelhowe, H. (2015). Designing digital fabrication learning environments for bildung: Implications from ten years of physical computing workshops. *International Journal of Child-Computer Interaction; Digital Fabrication in Education*, 5, 3-10. https://doi.org/10.1016/j.ijcci.2015.08.001

Kirschner, F., Paas, F., Kirschner, P. A., & Janssen, J. (2011). Differential effects of problem-solving demands on individual and collaborative learning outcomes. *Learning and Instruction*, 21(4), 587-599. https://doi.org/10.1016/J.LEARNINSTRUC.2011.01.001

Krokfors, L., Kynäslahti, H., Stenberg, L., Toom, A., Maaranen, K., Jyrhämä, R., Byman, R., & Kansanen, P. (2011). Investigating Finnish teacher educators' views of research-based teacher education. *Teaching Education*, 22(1), 1-13. https://doi.org/10.1080/10476210.2010.542559

Lockhorst, D., Admiraal, W., & Pilot, A. (2010). CSCL in teacher training: What learning tasks lead to collaboration? *Technology, Pedagogy and Education*, 19(1), 63-78. https://doi.org/10.1080/14759390903579190

Marsh, J., Arnseth, H. C., & Kumpulainen, K. (2018). Maker Literacies and Maker Citizenship in the MakEY (Makerspaces in the Early Years) Project. *Multimodal Technologies and Interaction*, 2(3), 50. https://doi.org/10.3390/mti2030050

Nelson, H., & Stolterman, E. (2003). *The design way. Intentional change in an unpredictable world*. New Jersey: Educational Technology Publications.

Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2017). Reviewing the affordances of tangible programming languages: Implications for design and practice. *2017 IEEE Global Engineering Education Conference (EDUCON)*, 1811–1816. https://doi.org/10.1109/EDUCON.2017.7943096

Posch, I., & Fitzpatrick, G. (2012). First steps in the FabLab: Experiences engaging children. *Proceedings of the 24th Australian Computer-Human Interaction Conference, Australia*, 497-500. https://doi.org/10.1145/2414536.2414612

Przybylla, M., & Romeike, R. (2014). Physical computing and its scope - Towards a constructionist computer science curriculum with physical computing. *Informatics in Education*, 13, 241-254. https://doi.org/10.15388/infedu.2014.05

Pucci, E. L., & Mulder, I. (2015). Star(t) to Shine: Unlocking Hidden Talents Through Sharing and Making. In N. Streitz & P. Markopoulos (Eds.), *Distributed, Ambient, and Pervasive Interactions. DAPI 2015* (pp. 85–96). https://doi.org/10.1007/978-3-319-20804-6_8

Schwartz, L. H., DiGiacomo, D., & Gutierrez, K. D. (2013). Diving into practice with children and undergraduates: A cultural historical approach to instantiating making and tinkering activity in a designed learning ecology. *11th International Conference of the Learning Sciences: Learning and Becoming in Practice*, 2(11), 70–77.

Seitamaa-Hakkarainen, P. (2011). Design based learning in craft education: Authentic problems and materialization of design thinking, design learning and well-being. In H. Ruismäki & Ruokonen, I. (Eds.) *Design Learning and Well-being. Proceedings of 4th International Journal of Intercultural Arts Education* (pp. 3-14). University of Helsinki.

Sentance, S., Waite, J., Hodges, S., MacLeod, E., & Yeomans, L. E. (2017). 'Creating cool stuff' - Pupils' experience of the BBC micro:bit. *Proceedings of the 48th ACM Technical Symposium on Computer Science Education: SIGCSE 2017*, 531-536. https://doi.org/10.1145/3017680.3017749

Sheffield, R., Koul, R., Blackley, S., & Maynard, N. (2017). Makerspace in STEM for girls: a physical space to develop twenty-first-century skills. *Educational Media International*, 54(2), 148–164. https://doi.org/10.1080/09523987.2017.1362812

Sheridan, K., Halverson, E., Litts, B., Brahms, L., Jacobs-Priebe, L., & Ovens. T. (2014). Learning in the making: A comparative case study of three maker spaces. *Harvard Educational Review*, *84*, 505-535. https://doi.org/10.17763/haer.84.4.brr34733723j648u

Smith, R. C., Iversen, O. S., & Hjorth, M. (2015). Design thinking for digital fabrication in education. *International Journal of Child-Computer Interaction*, 5, 20-28. https://doi.org/10.1016/j.ijcci.2015.10.002

Somanath, S., Morrison, L., Hughes, J., Sharlin, E., & Sousa, M. C. (2016). Engaging 'at-risk' students through maker culture activities. *Proceedings of the TEI'16: Tenth International Conference on Tangible and Embedded Interaction, Netherlands*, 150-158. https://doi.org/10.1145/2839462.2839482

Stager, G. (2013). Papert's Prison Fab Lab: Implications for the Maker Movement and Education Design. *Conference: Proceedings of the 12th International Conference on Interaction Design and Children*, 487-490. https://doi.org/10.1145/2485760.2485811

Volet, S., Vauras, M., Salo, A.-E., & Khosa, D. (2017). Individual contributions in student-led collaborative learning: Insights from two analytical approaches to explain the quality of group outcome. *Learning and Individual Differences*, 53, 79-92. https://doi.org/10.1016/j.lindif.2016.11.006

Vossoughi, S., & Bevan, B. (2014). *Making and tinkering: A review of the literature*. Washington, DC: National Research Council.

Vuopala, E., Näykki, P., Isohätälä, J. & Järvelä, S. (2019). Knowledge Co-Construction Activities and Task-Related Monitoring in Scripted Collaborative Learning. *Learning, Culture, and Social Interaction*, 21(), 234-249. https://doi.org/10.1016/j.lcsi.2019.03.011

Yin, R. (2002). *Case study research: Design and methods.* Thousand Oaks, CA: SAGE Publications.

**Appendix1**

Self-Evaluation

Name: ________________________________________

| | | | |
|---|---|---|---|
|  **totally agree** |  **agree** |  **disagree** |  **totally disagree** |

| | |
|---|---|
| I participated in the group activities. |  |
| I helped others in the group. |  |
| I contributed useful ideas. |  |
| I listened to others in the group. |  |
| I completed my work on time. |  |

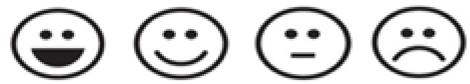
How did I feel during the project?

Why?

What did I learn from this project?

**Group Evaluation**

Names:

| | |
|---|---|
| We did an excellent job. |  |
| We worked together. |  |
| We helped each other. |  |
| We shared and listened to each other’s ideas. |  |
| We completed our project on time. |  |

Things we did well:

Things we need to improve:

Table 1

*Coding Scheme of the Questionnaires and Final Presentations*

| **Category** | **Coding Rule** | **Data Example** |
|---|---|---|
| Programming | Participant expressed that he/she learnt or learnt more how to do programming with micro:bit. | *'I learned to program with micro:bit.'* |
| Other technical skills | Participant expressed how his/her technical skills improved during the project. | *'I learned to use Tinkercad better.'* |
| English language | Participant expressed that his/her English language skills improved during the project. | *'I know more English.'* |
| Study skills | Participant expressed how he/she learnt to cooperate. | *'I learnt how to work in a group.'* |
| Other | Participant expressed that he/she didn't learn anything or couldn't answer the question. | *'Nothing'* |

Table 2

*Coding Schemes of the Final Fabrication Products and Group Presentations*

| **Category** | **Examples of Elements Included** |
|---|---|
| Micro:bit | Door that opens and get closed<br>LED lights |
| 3D-printed | Tables, chairs and computer |
| Laser-cut | Walls for the room, mirror, ceiling lamp and bookshelves |
| Traditional handicrafts | Curtains, sofa, pillows and chimney |

Table 3

*Students' Perceptions of Their Own Participation in the Group Work*

| Statement/Answers (f, %) | Totally Agree | Agree | Disagree | Totally Disagree |
|---|---|---|---|---|
| I participated in the group activities. | 4 (22%) | 13 (72%) | 1 (6%) | 0 (0%) |
| I helped others in the group. | 1 (6%) | 14 (77%) | 3 (17%) | 0 (0%) |
| I contributed useful ideas. | 8 (44%) | 10 (56%) | 0 (0%) | 0 (0%) |
| I listened to others in the group. | 5 (28%) | 12 (66%) | 0 (0%) | 1 (6%) |
| I completed my work on time. | 7 (39%) | 9 (50%) | 2 (11%) | 0 (0%) |

Table 4

*Students' Perceptions of Their Group Work*

| Statement/Answers (f, %) | Totally Agree | Agree | Disagree | Totally Disagree |
|---|---|---|---|---|
| We did an excellent job. | 11 (61%) | 6 (33%) | 1 (6%) | 0 (0%) |
| We worked together. | 6 (33%) | 11 (61%) | 1 (6%) | 0 (0%) |
| We helped each other. | 3 (16%) | 14 (78%) | 1 (6%) | 0 (0%) |
| We shared and listened to each other's ideas. | 9 (50%) | 8 (44%) | 1 (6%) | 0 (0%) |
| We completed our project on time. | 15 (83%) | 3 (17%) | 0 (0%) | 0 (0%) |