Making with Micro:bit

Teachers and Students Learning 21st Century Competences through the Innovation Process

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ABSTRACT

Innokas Network works with schools and other stakeholders to develop 21st Century Competences in education. In this work we present a maker pilot study in which Innokas Network introduced Finnish teachers to the Innovation Process and the Micro:bit programmable device for supporting students' 21st Century Competences. We show preliminary results of the study and discuss the relevance of maker projects and the Innovation Process for learning 21st Century Competences in the Finnish educational context.

100 participating Finnish teachers received in-service training in Micro:bit technology and learned to apply the technology within the Innovation Process. After the training, the teachers used the technology in class projects. They reported on their projects using blog narratives and research questionnaires. In addition, 850 participating students answered a questionnaire on their experiences. The results of an initial analysis point to a positive view of the maker-related Innovation Process and Micro:bit technology as a way for both teachers and students to learn 21st Century Competences.

CCS CONCEPTS

• Education • Applied Computing • Computing Education

KEYWORDS

Maker culture, 21st Century Competences, Innovation Process, Micro:bit, programming, Technology.

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1 Maker Culture, 21st Century Competences and Technology in the Finnish Educational Context

Living in the future society requires a set of knowledge and competences; referred to as *21st Century Competences*, *generic skills*, *transversal competences*, or *key competences*, which today's education needs to address globally[1,2] (see Table 1). Students are preparing for a future work life with jobs that may have not been created yet[3,4]. Maker-centered activities may offer a good approach to learning future competences requiring creativity and innovativeness.

In the Finnish National Curriculum[5], learning is tied to *transversal competences*, the Finnish interpretation of 21st Century Competences, which are: 1) Thinking and learning to learn, 2) Cultural competence, interaction and presenting, 3) Every day skills and taking care of yourself, 4) Multi-literacy, 5) ICT competence, 6) Working life-skills and entrepreneurship and 7) Participation, influence and building a sustainable future.

The transversal competences are meant to be developed in all school subjects and especially in *creative interdisciplinary projects*, which are mandatory for all grades. In addition, computational thinking, robotics, and automation in the living environment are a part of the curriculum and are also developed in an interdisciplinary way across several school subjects. In primary school these are present in the mathematics and environmental studies curriculum and in lower secondary they are a part of mathematics, physics and crafts studies. Therefore, the Finnish educational system provides a unique forum for maker-centered activities and the integration of technology into everyday classroom practice. However, promoting future competences in education has been found challenging in Finland[6]. The challenges are faced on different levels from classroom composition to teacher education. Arguably, especially computational thinking poses the greatest challenge to teachers due to a lack of prior experience and training.

Table 1. 21st Century Competences[3]

Competences needed in the 21st century	Examples of competences
Ways of thinking	Creative and critical thinking Use of knowledge and information interactively Learning to learn, use of metacognition
Ways of working	Communication, collaboration and networking (team work in a heterogeneous group) Competence to act autonomously Identifying issues (questioning), arriving at conclusions based on information, explaining phenomena, organizing information Competence to use both creative and critical thinking in problem-solving and decision-making Use of ICT tools interactively Managing and resolving conflicts
Tools for working	Literacy: knowledge (network of concepts), nature of knowledge, attitude (willingness to engage) ICT literacy Skills needed in inquiry and problem-solving Moral and ethical code
Context for working	Personal, citizenship Social, local Working life, career Global
Attitude needed for working	Willingness to use knowledge (motivation) Self-efficacy

Several studies[7] indicate that methods where knowledge is built collaboratively in iterative cycles, working on real-life challenges to build a shared artefact, are beneficial to students' competence building. The concept of 'learning by making'[8] contributes insight into how students can be engaged in learning. However, it can be challenging for a teacher to change classroom settings into maker-spaces. A variety of teaching methods are needed to aid students in building their 21st Century Competence through maker-centered activity.

Maker-centered activities can be approached through *Innovation Education*, a Finnish model of maker activities for the pedagogical setting developed within Innokas Network. In Innovation Education, students learn both transversal competences (21st Century Competences) and subject knowledge through collaborative maker activities; being creative and learning by doing. This practice is rooted in the Finnish tradition of having textile- and woodcrafts as part of the curriculum with appropriate spaces and tools for maker-activities already set up in schools. The maker movement adds to this tradition by updating current spaces with digital fabrication tools.

Key objectives of Innovation Education include developing critical and creative thinking, understanding the built environment, using innovative working methods, and making use of ubiquitous technology. Technology is seen both as a tool for learning and creating new innovations, as well as an object of learning. Students are guided to understand their built environment from observations of technology in everyday life to being able to produce functioning programmable innovations. Learning programming concepts and the general use of technology is not just about learning the basics but also about applying the learned skills in different contexts.

Innovation Education is carried out through the *Innovation Process* (See Figure 1). It combines evidence-based teaching and learning strategies from knowledge-creation[9], collaborative designing[10], creative problem-solving in science and technology education[11], and support for learning[12].

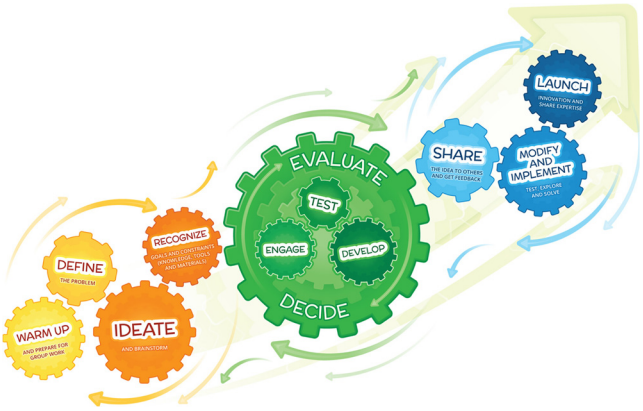

Figure 1. The Innovation Process

The Innovation Process begins with a *warm-up* phase where students engage in group work. If the teacher plans to have students use specific technological tools, their basics should be taught at this point. Next, teacher or students *define* the problem, for which students begin to innovate solutions. Students brainstorm and *ideate* as many different ideas as possible. The ideas are reviewed by *recognizing* goals and constraints such as the available technological tools or materials. Selected ideas are *evaluated* through *testing* and *development*, and the best idea is chosen for further work. The chosen idea is then *shared* with other groups or experts for feedback. After receiving feedback the group starts to make prototypes, which means *modifying and implementing* the *innovation artefact*; designs or products. When ready, the innovation is *launched* through a presentation to a larger audience. It is noteworthy that the Innovation Process does not necessarily progress linearly through these phases. Especially in the implementation phase the group may notice that the chosen solution did not work and revert to ideating new solutions.

2 Adopting the Micro:bit as a maker tool

In this study we used Micro:bit, a tiny programmable physical computing device developed by the BBC for teaching and learning programming[13]. We introduced Micro:bit into Finnish teaching both for teaching programming basics to students and as the technological component in the Innovation Process. The Micro:bit technology and Innovation Process pilot was initiated when the interest of the Micro:bit Foundation to introduce their tool to the Finnish education context met the Innokas Network interest to

research and develop the creative use of technology, the maker movement and the Innovation Process in schools.

The pilot effort supports the Finnish National Curriculum aims of promoting transversal competences through interdisciplinary modules. In particular, programming is seen as an area where teachers need support, as it is, for most teachers, a new undertaking.

After Innokas Network trainers tested the Micro:bit tool and found it suitable for pedagogical use in Finnish schools, a partnership was formed, and a pilot plan was created to disseminate the technology and the Innovation Process through targeted in-service training for teachers.

From 150 applicants, 50 participating schools were chosen for the pilot. The selection was based on geographical location, evaluation of the provided motivational letters and on grade levels. A two-day in-service training session was organized for two teachers from each school. The first day included basic training in programming and on the use of Micro:bit. During the second day the teachers immersed in an Innovation Process, using Micro:bit as the technology around which they innovated an artefact. The purpose of having teachers work through the Innovation Process themselves was to help them adapt to a new way of learning and teaching, with the trainer providing an example of the *student experience* as well as a *teaching model*. In addition to the training the teachers received 10 Micro:bits each – enough for their class to work with in pairs.

A total of 100 teachers from 50 schools participated in the pilot. In the schools, the total study group included 177 classes and 1960 students: pre-primary students to second graders aged 6 to 8 eight years (4%, n=69), third to sixth graders aged 9 to 12 years (48%, n=939), seventh to ninth graders aged 13 to 15 years (44%, n=866) and upper-secondary students aged 16 to 18 years (2%, n=47). As with all of Innokas Network's initiatives, the Micro:bit pilot included both research and development perspectives. Teachers and schools committed to using the Micro:bit in a project of their choice in their classroom and to reporting on it in a blog-post on the Innokas Network web site.

Moreover, teachers and students were provided questionnaires on their experiences with Micro:bit, as well as on their perspectives on 21st Century Competences (such as programming), maker-activities and innovativeness. Teachers answered a questionnaire at the end of the project (n=78). Students (n=850) completed a questionnaire immediately after finishing the project.

Both students and teachers were asked about their experience in developing 21st Century Competence during their Micro:bit maker project. The questionnaires were operationalized to include aspects regarding different activity or actions based on the definition of 21st Century Competence. Teacher aspects included developing teaching, problem solving, reflection, working together, supporting colleagues, and using new tools. Student aspects included presenting new ideas, solving problems, asking questions, working together, building, helping others, as well as making decisions and new innovations. Participants assessed both the possibility and importance of each aspect by evaluating it in two dimensions: 1) if they had the *opportunity* to perform this action/activity during the project and 2) if they viewed it as *important*.

In addition, the questionnaires included a variety of questions on the participants' experience, including: a) teacher evaluation of their programming competence before and after the pilot (school grade), b) if teachers would recommend Micro:bit as a tool for their peers, c) if they intend to continue using Micro:bit in their class, d) how easy and fun the students found Micro:bit programming, e) if the students found programming interesting and f) if the students were nervous about programming.

3 Preliminary results

Most of the maker projects conducted during the study were interdisciplinary, covering more than one subject in the project. The subjects included in the projects were mathematics (n=37), physics and chemistry (n=24), crafts (n=22), arts (n=16), Finnish language/literature (n=15), geography and biology (n=13), foreign languages (n=11), music (n=8), history (n=2) and physical education (n=1).

Most teachers reported that they had an opportunity to learn 21st Century Competences during the pilot (see Table 2.). Most teachers had the opportunity to develop their teaching and solve challenges relating to the new teaching situation or tool and viewed these as important for them.

Table 2. Teachers' development of 21st Century Competences during the study (n=78)

Competence aspect	Had opportunity to do	Viewed as important
I developed my teaching and methods (Ways of thinking)	93.65%	92.06%
I solved challenges relating to new teaching situation or tool (Ways of working)	92.06%	93.65%
I collaborated with other teachers (Ways of working)	77.78%	87.30%
I used new tools and materials (e.g. maker-materials, new technologies) (Tools for working)	66.67%	84.13%
I supported other teachers in their work (Context for working)	73.02%	88.89%
I reflected my actions on what I did in the past (Attitude needed for working)	85.71%	87.30%

Most students reported that they had the opportunity to work with others, solve problems and ask questions (See Table 3.) Of the aspects, working with others was viewed as the most important.

Table 3. Students' development of 21st Century Competences during the study (n=850)

Competence aspect	Had opportunity to do	Viewed as important
Asking questions (Ways of thinking)	89.20%	57.04%
Making decisions (Ways thinking)	78.95	54.77%
Working with others (Ways of working)	93.29%	75.73%
Presenting ideas (Ways of working)	79.36%	46.52%
Building / making / tinkering (Tools for working)	70.18%	51.72%
Helping others (Context for working)	79.93%	62.13%
Making new innovations (Attitude needed for working)	59.54%	41.44%
Solving problems (Attitude needed for working)	81.82%	54.11%

On additional questions regarding participants' experience during the pilot, they reported positive reactions: a) teachers reported that their own programming skills increased by one school grade from 7.1 to 8.1 (on a scale from 4 to 10) during the project, b) teachers would recommend Micro:bit to their peers as a tool for teaching programming and c) they intend to continue using Micro:bit, d) students found the Micro:bit to be easy and fun to use, much like their peers in the UK[13], e) students reported that programming is interesting to them, and f) they are not nervous about it.

4 Discussion: Making it to the 21st Century

Based on the presented preliminary results, maker-centered activities can provide a good approach for learning 21st Century Competences. However, it is important to understand the contextual nature of these activities; i.e. how these processes are guided and realized in schools. The Innovation Process seems to support the learning of 21st Century Competences for both teachers and students in the Finnish context. In this framework teachers become learners themselves before being able to teach these competences to students.

Noteworthy for this pilot is that the projects done in schools were interdisciplinary by nature, suggesting a possibility for maker and innovation centered processes to support the integration of different subjects and interdisciplinary teaching and learning.

The Micro:bit was seen as easy to adopt and use in the Innovation Process and maker-centered activities. It provides opportunities as tool for creating new innovations and also as an object of learning.

Further analysis of the collected data is needed to understand the relationship between participant perspectives on 21st Century Competence and for instance their general views on programming. Programming is viewed as a part of transversal competences, but the questionnaire included specific questions on it because of its newness to most teachers and students.

Overall, the Micro:bit pilot can be viewed as a successful introduction of maker related Innovation Process and new technology to Finnish teachers and students. Reactions to the process, technology and training were positive, and teachers implemented these in multiple maker related ways. Since the pilot, the Innokas Network has organized further maker related Innovation Process and Micro:bit training and the tool is in frequent use as part of the network toolset.

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