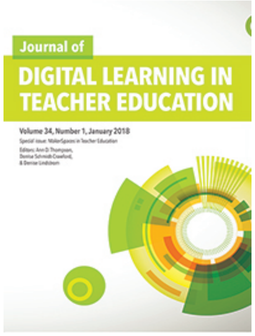

Journal of Digital Learning in Teacher Education

ISSN: 2153-2974 (Print) 2332-7383 (Online) Journal homepage: http://www.tandfonline.com/loi/ujdl20

Makerspaces Across Settings: Didactic Design for Programming in Formal and Informal Teacher Education in the Nordic Countries

Susanne Kjällander, Anna Åkerfeldt, Linda Mannila & Peter Parnes

JDLTE | Vol. 34, No. 1, pp. 18–30 | © 2018 ISTE | iste.org/jdlte
DOI: 10.1080/21532974.2017.1387831

Makerspaces Across Settings: Didactic Design for Programming in Formal and Informal Teacher Education in the Nordic Countries

Susanne Kjällander & Anna Åkerfeldt
Stockholm University

Linda Mannila
Linköping University

Peter Parnes
Luleå University of Technology

Abstract

For education to provide knowledge reflecting our current and future society, many countries are revising their curricula, including a vivid discussion on digital competence, programming and computational thinking. This article builds an understanding of the maker movement in relation to education in programming, by demonstrating challenges and possibilities in the interface between Makerspaces and teacher education. Three different Nordic initiatives are presented and their designs for learning are analysed. The article illustrates how Makerspaces and teacher education can be transformed by each other; how Makerspaces can be used in programming activities and what challenges and possibilities emerge in the meeting between the two. The results highlight a core aspect of the maker movement: authenticity. Designs for learning have different levels of authenticity, but in all cases authenticity has been a positive factor. These hands-on learning environments are designed to foster collaboration, share ideas and innovation with people from different backgrounds to transform and form multimodal representations together. In the interface between the formal and informal a potential for inclusion and creation of spaces that reach individuals from different backgrounds is found. Mobile learning is a phenomenon that the making movement together with teacher education can make use of, at for example practice schools, university campuses, mobile Makerspaces or "open-door"-approaches. In the digital environment learning is distributed, but collaboration between formal and informal education is so far complicated to establish, meaning that the academy needs to find more creative and flexible ways of making connections outside the academy.

Introduction, Aim, and Research Questions

Digital devices are ubiquitous in Western society, and the digitalization affects everyone and everything in different ways. For education to provide the general knowledge reflecting our current and future society, many countries are revising their K–12 curricula. Digital competence (European Commission [EC], 2006) is highlighted in this discussion, commonly including a vivid discussion on integrating programming in formal education around the world. Voices are raised saying that every child should learn how to program and develop computational thinking (Wing, 2006) skills. In October 2015, the results from a European Union (EU) commission survey showed that more than 75% of 21 surveyed European countries (16/21) had integrated programming in their curriculum to some extent (Balanskat & Engelhart, 2015). One year later, the commission published a report going into depth on how this is accomplished in practice (Bocconi &

Chioccariello, 2016), at the same time presenting the results from a new survey showing yet an increasing proportion of European countries including programming in their curricula. As a natural consequence of this transformative work, teacher education (TE) ought to be revised as well.

The Finnish national curriculum for basic education (grades 1–9) was revised in 2014 and came into force in fall 2016. As a result, all students are to develop their digital competence, including learning to program, in both mathematics and craft explicitly, as well as in the form of a transdisciplinary trait in all other subjects. The new curriculum has naturally caused a large need for in-service teacher training. Development projects and teacher training efforts are funded by the state and carried out throughout the country. In addition, the curriculum changes have raised the question on how to develop the TE for preservice training to address the new needs. In Sweden, the K–9 curriculum will include programming and digital competence starting in fall 2018, implemented in all subjects generally and in mathematics and technology science specifically.

Both digital competence and programming are new terms in a Nordic school context, and there is hence a need for clarifying what is meant. This holds particularly for programming, which is associated with stereotypical views focusing on code and isolated work settings. The Swedish National Agency for Education (Skolverket, 2017) has published additional material for the revised curriculum. It stresses that the focus is not on coding skills, but on programming as a pedagogical tool and problem-solving process, including many phases. Programming should also be seen in a wider context, including "creation, controlling and regulating, simulations and democratic dimensions" (p. 10). This also emphasizes the importance of seeing programming in this wider perspective both as a basis for teaching and as part of all aspects of digital competence.

Even when programming was not yet part of the curriculum, it was taught on a voluntary basis at different age levels and in a range of schools throughout the Nordic countries using a variety of resources and equipment such as robots and other "toys." Sometimes the didactic design with a focus on the learning process and aim of the activity is lost in the massive flow of new and exciting digital tools. The Organization for Economic Cooperation and Development (OECD) report "Students, Computers and Learning" (2015) highlights the need for pedagogically sound strategies and clear goals when using technology in education; otherwise, there is a risk of the technology obstructing instead of promoting learning.

In this article, we argue that the maker movement can be used as a base when designing activities for introducing programming as an interdisciplinary tool in K–12 education. The maker movement is an extension of the traditional do-it-yourself movement, adding digital fabrication, including techniques, tools, and materials, previously only available to larger organizations and institutions. Halverson and Sheridan (2014) describe three components of the maker movement "making as a set of activities, makerspaces as communities of practice, and makers as identities of participation" (p. 496)

A maker can engage in making anywhere, but special physical areas or community of practice, *makerspaces*, are also built in various settings and sizes for bringing together makers for learning from each other and sharing ideas. The focus on learning is foregrounded in makerspaces, rather than education. Learning as an integrated process across subjects and toward process-oriented authentic tasks, built upon individuals' interest and engagement (Halverson & Sheridan, 2014). According to Lindstrom, Thompson, and Schmidt-Crawford (2017) with a reference to Agency by Design (2015), it is important not only to provide educators with tools and strategies, but also to strengthen the idea that the most important benefit of makerspaces is to provide children with a sense of self that empowers them to engage in shaping their world. A pedagogue in a Swedish research project expressed it as the following: "All children shall have the opportunity to develop an understanding that it is humans who lie behind the computers', the machines' and the robots' actions" (Kjällander, 2016, p. 20). Until a few years back, the maker movement was seen in out-of-school spaces such as homes, museums, after-school activities, and camps, as well as online (Lindstrom et al., 2017; Peppler & Bender, 2013), but now makerspaces are developing more within the frames of school, both internationally (Lindstrom et al., 2017; Niederhauser & Schrum, 2016) and in the Nordic countries. TE, however, is not keeping pace with this development. This is not a country-unique scenario, and, for example, Borthwick and Hansen (2017) pinpoint that the National Educational Technology Plan in the United States from 2016 states that, unlike today, there should be no uncertainty about whether a learner entering a college lecture hall will encounter a lecturer who is fully capable of taking advantage of digital resources to transform students' learning. This article draws on and shows examples of programming activities in the intersection between makerspaces and formal teacher education. The aims of this article are to (a) build an understanding of the maker movement in relation to formal education in programming; (b) demonstrate how makerspaces can be integrated into teaching practice and TE, and (c) analyze possibilities and challenges in the interface between the two different learning environments.

Research questions are:

- How can makerspaces and formal teacher education (TE) be transformed by each other?
- How can makerspaces be used in programming activities in TE?
- What challenges and possibilities emerge when informal makerspaces and formal educational settings meet?

Technologies in the Nordic schools are dense, although this varies from school to school. However, the use of technologies for learning and especially how to use and teach programming with the support of technologies are not always appropriate. However, makerspaces and other informal initiatives are active nationally and can potentially play a role in supporting the introduction of programming in formal education. Programming (related concepts of computational thinking, coding, computational literacy, algorithmic thinking) in primary education is still a rather new phenomenon, and there is no common understanding about what this "new" content should entail in primary education (Henderson, 2009; Rolandsson & Skogh, 2014; Jun et. al., 2014; Basu et al., 2016; Bocconi & Chioccariello, 2016). Today, municipalities and individual schools and teachers in the Nordic countries teach programming in their classes. Some municipalities have established support centers for teachers and their pupils to take part in programming. Even more common is that there are private initiatives that arrange programming courses or workshops as after school activities, often at makerspaces. The lack of research in this area calls for studies investigating different aspects of both teaching and learning in both formal and informal contexts. A great concern for education is currently the deficient competence of teachers, which obviously casts light on TE.

Earlier Research and Survey of the Field

There is a pervasive presence of digital devices, and they provide fundamental support and organize people's everyday lives. Programming plays a great role in people's everyday lives too. Tools for programming have been developed, such as block programming tools, which makes programming easier, in contrast to textually written code such as, for example, C++. Because of the availability of block programming tools, the rapid technology development, and the ubiquitous nature of computers and digital devices in our daily life, new perspectives on programming are being formulated. In the 1980s, Papert (1980) coined the term *computational thinking*. Wing (2008) states that thinking like a computer scientist requires thinking at multiple levels of abstraction, and she further argues that all children should have the opportunity to develop their capacity for computational thinking already in their early school years. According to Wing, "computational thinking is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability" (Wing, 2006, p. 33). Computational literacy (Grover & Pea, 2013), algorithmic thinking (Bocconi & Chioccariello, 2016), coding (Sáez López, González, & Cano, 2016), ethno computing (Eglash, Gilbert, & Foster, 2013), and computational participation (Kafai, 2016) are also related concepts used in the literature, which brings forward the need to explore what programming unfolds and entails in educational settings. Programming is sometimes seen as the mere writing of code ("coding"), but looking at programming as a process also includes, for example, problem statement, problem solving, testing, and documentation and logical thinking, as well as a structural approach and ability to generalize (Björk, 1983; Heintz, Mannila, Nygårds, Parnes, & Regnell, 2015). Csizmadia et. al. (2015; Mannila et al., 2014) describe computational thinking as a cognitive process, involving logical reasoning, through which problems are solved and an understanding of artifacts, procedures, and systems is created. Norway's curriculum has digital skills as a fifth basic skill added to speaking, reading, writing, and numeracy (Norwegian Ministry of Education and Research, 2012).

A few years ago, Krumsvik (2011) highlighted the lack of adequate competencies among higher education teachers. More recent research shows that there is still a lack of digital strategies and competencies at universities (Tømte, Kårstein, & Olsen, 2013). Krumsvik calls for establishing a framework for professional development for teacher educators at TE departments (Krumsvik, 2011). Two research projects with the aim of identifying the digital technology demands of TE (Newhouse, Cooper, & Pagram, 2015) conclude that TE educators should model technology by, for example, problem solving, creative thinking, and information and communication technology (ICT) competencies, but should also learn to capitalize on the affordances of students bringing their own devices to campus. Their students should be familiar with digital devices during both their studies and their teaching practices so that they are prepared to use them in their own teaching. According to Herring, Thomas, and Redmond (2014), the notion of TPACK is relevant here: TE should develop technology, pedagogy, and content knowledge (TPACK). There is a lack of critical voices in previous research toward implementation of technologies in education and toward implementing programming in schools and TE. The research within the field is mostly positive toward the use of technologies, and the didactic questions and design of activities tend to fall into the background. In this article, we highlight and foreground the didactic design instead of digital technologies. As the TE lags behind in using digital tools and even more in teaching programming, we argue that one way is to collaborate and share knowledge within makerspaces.

Programming in Formal Educational Settings

In higher education, computer science is a well-established research field and programming has been taught for a long time. In recent years many online educational opportunities, such as massive online open courses (MOOCs) on Udacity, EdX, Udemy, Lynda.com, and so on, have emerged where anybody interested can learn programming at their own pace, both at beginners' and advanced levels. These online services are an alternative to traditional higher education courses, as they provide interested persons (including teachers), wherever they are, the opportunity to learn more about computer science and programming. Online initiatives in TE have been noticed to be successful (see, e.g., Evens et al., 2017). Note though that these are general programming courses, not covering the didactical questions and challenges faced by teachers in basic education. Currently there are no overarching formal online courses targeting teachers, which can be a potential problem. There are, however, other initiatives such as free resources, communities, and courses where teachers can share and get ideas for introducing programming in their teaching. For instance, a Swedish school provides a portal with freely available courses on programming for teachers at different levels (kursportalen.se). In Finland, online courses for teachers are arranged annually showing how to introduce programming in different subjects in Swedish and Finnish. The Swedish National Agency for Education is currently developing online programming modules for teachers, in preparation for the revised curriculum.

In March 2017, the Swedish government accepted a revision of the curricula for primary education building on a plan made by Skolverket (2017). Because of this revision, the focus will be broadened from information technology to digital competence and programming. This development can be seen all around the world, as all children's right to experience programming in education has become a vivid discussion topic (Informatics Europe and ACM Europe, 2013; White House, 2016). Consequently, many countries have decided to implement programming in education. An EU report from 2015 (Balanski & Engelhart, 2015) showed that 16 of 21 countries in the EU have introduced programming in the curriculum at the local, regional, or national level. There are two distinct tracks in the way countries introduce programming in school: (a) computer science being introduced as a separate subject, or (b) integrating the content with already existing subjects—notably mathematics (The Royal Society, 2012). The age at which countries introduce programming varies within the age range of 5 to 16 years.

Teachers' beliefs, thoughts, and intentions about programming in relation to their own teaching practice have been studied by Rolandsson (2015), who presents an image of teachers' exploration of the subject of trying to teach programming in a great variety of ways. Despite this, they reckon that many students find it hard to understand the subject. Furthermore, programming education is perceived as exclusive, since teachers believe that teaching programming is difficult. On the other hand, the study illustrates that students often are expected to teach themselves by coding on their own. Teachers find strategies for as many students as possible to be trained and to develop their abilities to solve problems. However, the result indicate that teachers often lack the belief that all students can learn programming; instead, they believe that only those students who already have an analytical and logical ability can learn to program.

Programming in Makerspaces

In informal educational settings, many initiatives to support children interesting in learning to program have formed over the last years. Most of these are driven by individual driving spirits on either paid or unpaid time. Internationally larger efforts include Hour of Code (code.org), Khan Academy (khanacademy.org), and the Scratch Project (scratch.mit.edu). In the Nordic countries, a number of national smaller efforts exist with various objectives. Some of these initiatives target programming specifically, while others pursue a more general approach to computer science and creation. These are examples of informal educational settings where young individuals can be inspired to learn more about digital tools in general, and about programming in particular.

Research on computational thinking and programming at young ages is rare, in both formal and informal educational settings. Even less research has been conducted between and across these practices. Research has mainly been conducted within the field of computer science. Research on children's learning does require both didactical expertise and the subject knowledge of computer scientists. Research collaboration between didactic science and computer science is thus crucial. In addition to being better able to address the questions involved, interdisciplinary research makes it possible for the disciplines to mutually develop each other, and this is our intention in this article. Some interdisciplinary research has already been conducted, which we have highlighted in the preceding.

Designs for Learning

The theoretical approach of "designs for learning" is here used to understand the merging of makerspace and TE. Designs for learning is drawn from a social semiotic and multimodal framework (Jewitt, 2009; Kress, 2010; Selander, 2017; Selander & Kress, 2010). Additionally, we use a design-based research (DBR) approach (Barab, Squire, & Barab, 2004).

Designs for Learning is used as it provides an understanding of digital devices as meaning-making, actional, visual, and linguistic resources (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001), which can be used to interact within, for example, programming. With this approach, learning environments include an ensemble of different modes, such as symbols, music, and colors, simultaneously, holding possibilities for meaning-making (Kress, 2010; Kress & van Leeuwen, 2006). The combination of perspectives embraces changes in society, and it provides a set of conceptions to describe, analyze, and understand learning environments. The article has a didactic perspective, which means that it focuses on how the didactic designs (Selander & Kress, 2010) of "making" culture are transformed and formed by teachers in formal educational settings, as well as by other leaders or instructors in informal educational settings. We focus on designs for learning, which entail how existing learning resources are used and how activities across formal and informal settings can be organised when children learn programming. Designs for learning is a way of thinking forward. It involves change and supports the shaping of purposeful connection on different levels (Selander, 2017). It has also to do with the conditions for learning, bringing to the fore how spaces for learning can be organized in a changing educational landscape.

Presentation of Study

To create new connections and spaces for pupils and TE students to participate and learn how to program, we present three cases on how these learning spaces can be designed in the interface between makerspace and formal higher education. Based on a Nordic research outlook, three case studies have been selected as examples: one from Finland and two from Sweden. Several research projects support the cases that are analyzed and presented in this article as illustrative empirical examples of the connection between the makerspace movement and formal education, when it comes to programming. In this article, a distinction is made between formal and informal educational setting and the interface between them is of high interest. Three cases are presented as representations of three running projects in the interface between makerspace and teacher education.

Methodological Concerns

The cases are described using theoretical notions of designs for learning.

Two different settings are analyzed but the interface between them are the focal point of this article:

1. Formal educational settings: teachers' implementation, instruction, and experience of designing lessons, which integrate programming in their teaching in PK–12 education.
2. Informal educational settings: makerspaces and the involved organizers' and instructors' experience of designing programming activities.

The analyzed cases are discussed in terms of the potentials and challenges of teaching programming in the interface between makerspaces and formal teacher education and how makerspace environments can be implemented in teacher education. As a conclusion, a few potential synergy effects are highlighted along, with a discussion on how teachers' didactic design and digital competence potentially can be developed across the different settings.

Results Illustrated in Three Makerspace Cases

Case: Luleå Makerspace

Luleå Makerspace is a nonprofit organization that was founded in 2013 with the main purpose of being both a technical lab where participants could get access to various modern manufacturing devices and, more importantly, meeting places where persons of different backgrounds could meet and learn from each other. The makerspace has experimented with many different methods for activating visitors and getting them to learn from each other and by themselves. The space has welcomed many professional groups including teachers and artists to various workshops and longer development series. One example is Young Makers, where 15 youngsters were invited to develop their own idea by going from idea to prototype, not only learning a specific technology but rather learning what they need to realize their own personal prototype.

To get young women interested in technology, the makerspace has worked a lot with specific events like MakerGirl where only girls aged 9–15 years have been welcome to the workshops and the MakeHer initiative where only adult women are welcome. The overall goal with the latter is to create a setting and a learning space where women can feel more comfortable with learning programming on their own premises, as well as creating role models for girls.

In collaboration with Luleå University of Technology, a university makerspace has been created as well, and this university makerspace has attracted many students and teachers from the teachers' educational programs as a means to learn more about creation using modern technology. In parallel to this, several educational development projects between the computer science and the pedagogical departments have led to an increased knowledge of the new requirements and development of existing courses with the goal of producing teachers with knowledge in programming and the usage of digital tools in society in general.

The makerspace has welcomed a large number of groups of teachers, where they have gotten an introduction to various making related technologies in general and programming in particular. In collaboration with the School of Luleå, groups of both teachers and principals have been welcomed to the makerspace, and maker culture has been used at recruitment events to show practical applications of digital tools including programming. One specific example is workshops with preschool heads where they got to do hands-on creation with electronics incorporated into more classical building materials like paper and cloth. Another example is where a mix of teachers and principals in grades K–6 met several times at the makerspace during 2016–2017 to learn more about programming in relation to the changes in mathematics curriculum starting in autumn 2018. The learning is done around the Micro:bit computer.

Case: Väsby Makerspace—Stockholm University TE

For the past 4 years, preschool teacher students have attended a compulsory "digital block" in the middle term of their teacher education. The digital block is 4–5 weeks long and part of a longer course, which is about 5 months long. The students are introduced to theoretical perspectives on children's language development and communication, making a field observation studying children's communication in preschool, and through the lens of theoretical concepts they analyze their field observations, after which they write an essay combining their ethnographic empirical material with their chosen theoretical perspective. The essay concludes in a section where they elaborate and create a few didactic play-and-learn activities that are possible to use in preschool. The students' assignment in the digital block is to transform their knowledge and essays results (i.e., the didactic play-and-learn activities) into a play-and-learn app grounded in theoretical concepts. The students construct their app in PowerPoint, making use of the interactive and the nonlinear design and the possibilities to include interaction with the function "triggers" in the program—making it work like an app. It is also possible for the student to create animations and add sound effects to objects in their app. The app is graded with a 7-grade basis for assessment and presented at an event where preschool teachers and decision makers as well as media are invited. After the course, the students have a "teaching practice-course" where they use the application together with the children in their different preschools. A streak of programming and making has been introduced, in a modest way, during the last few years, and seminars and workshops about using stop motion for digital storytelling and the circuit board Makey Makey have been introduced during the digital block.

Initiative and voices are raised within the preschool TE to develop a "making lab." Inspiration to create such a lab has been grounded and has sprung from ideas and values from the maker movement. Ideas about spaces for learning for creative learning are foregrounded. In line with design thinking (Selander, 2017), we wanted to create new connection and a change of direction in the course, and therefore we initiated collaboration with a maker movement, in this case Väsby Makerspace.[1] The cooperation was initiated to meet existing objectives in the curriculum, but above all to meet the next national IT strategy from the National Agency for Education (Skolverket, 2016). The initiative came from teachers within preschool education, to broaden students' digital competence and gain deeper knowledge about why and how implementation of technologies affects education and our society (Facer, 2011). Väsby Makerspace serves as a creative center for IT crafts and can be seen as an extension of the municipal preschools and schools. Principals—through their preschools and schools—together with teacher students are invited to use the makerspace and gain access to the materials, skills, and methods to work with programming and digital competence. Workshops and lectures about digital technologies and education, as well as lessons or creation processes with information technology tools and materials, are offered. Here teacher students can discuss, train, program, and test three-dimensional (3D) printers, soldering stations, various types of computers,

[1]http://blogg.upplandsvasby.se/vasbymakerspace/

robots, and sound and light tools. Toward the end of 2017 the first group of teacher students took part in the maker workshop at Väsby Makerspace.

Case: Practice Schools and Mobile Makerspaces in Finland

In Finland, different scenarios and approaches have been suggested, to develop TE to prepare for the new curriculum and programming, with one being the development of makerspaces at so-called training schools.

Each Finnish TE has its own training school, in which teacher students engage in preservice practice, teaching pupils in authentic classroom settings. One of the training schools in southwestern Finland went through a large renovation process in 2016, and consequently both the space and the technology available are state-of-the-art. For the space and the technology to be used in a pedagogically viable and activating manner, there was a need for finding new teaching processes and pedagogical models supporting the new curriculum.

As a result, the Finnish National Agency for Education funded the project "Engaging and encouraging laboratory for active learning," aiming at investigating the possibilities of developing a mobile makerspace at a training school in Turku. In addition to designing the actual makerspace, the project also aims at building a model for how teachers can be trained in utilizing tools, ideas, and techniques from the maker movement in a variety of subjects and at different levels of education.

The rationale for creating a mobile makerspace was twofold: First, we wanted to make the equipment easily accessible for teachers throughout the school, which is large, with students spread over three floors. Second, we wanted to stress the idea that "making" can be used in a transdisciplinary way in many subjects, and hence without wanting to restrict access to the tools needed to one given physical space.

The main criteria when designing the makerspace were the following: mobile, easily accessible (both physically and mentally), possible to only borrow parts of the makerspace, and not too crowded (avoid tool overload, but rather focus on equipment with a track record and/or recommendations based on research). Larger maker equipment, such as 3D printers and laser cutters, will be stored in a physical place close to the craft classroom. The most important criteria for the storage place is that it is open to all teachers at any time.

During the school year 2017/2018, we will actively work together with teachers, as they adopt and evaluate programming and the use of a selected set of technology in their teaching (Makey Makey, Micro:bit, Lego Mindstorms, and AR/VR). In August, we offered "open door" events at the school, offering all teachers a low-threshold opportunity to try out the technology. Interested teachers will be selected as pilot teachers, with whom we will meet on a regular basis to help them become confident in using the technology of their choosing and develop ways in which they can use the technology in their teaching. In addition, we will arrange additional "open-door" hands-on events and a large seminar, where the pilot teachers can share their experience with colleagues not only in their own school but also with others. We already have pilot teachers working on using VR/AR for solving textual problems together with students in sixth grade, science teachers wanting to collect their own data, analyze them, and write programs, and teachers in arts, who want to create interactive artwork.

Summative Analysis

These three cases give some insight into how makerspaces' ideas and way of working can complement TE and formal school learning.

Designs for Learning With Authentic Settings

From a design theoretical perspective, learning has to do with production, and in these case studies we meet lots of makers in the act of producing: transforming and forming their own representations by programming. One of the core aspects of the maker movement is authenticity, which means that it is the participants—makers—and their interest that form the activity. In these three cases, activities and tasks have streaks of authenticity, which has meant a lot for these projects. People engage more with a real audience for their work, but also research has shown positive effects when engaging in authentic tasks in TE (see, e.g., Swinkels, Koopman, & Beijaard, 2013), and process-oriented authentic tasks are an important part in making culture (Halverson & Sheridan, 2014). This is partly illustrated in the cases. In the Stockholm/Väsby case, preschool teacher students made their own apps and put in a lot of extra effort and spare time, not only to transform their gained knowledge about children's language development and communication to an app, but also to make the apps usable, since they were going to use it in their own teaching in a group of preschoolers. Now, this cooperation is in an early stage, but there are great potentials for solving real-world problems. Also in Luleå Makerspace authenticity is highlighted, with teachers and principals meeting at the physical space to try out and understand programming as a transformative force of education in relation to, for example, the new curriculum. In the Finish training schools, this is taken even further with designed mobile makerspaces where TE teachers, teacher students, and pupils can meet and make in authentic classroom settings. There is a challenge regarding the number of students in TE, and organizing authentic tasks for more than 100 students at the same time not only requires resources but also is demanding to design when it comes to course criteria and assessment. Over the years the course criteria at Stockholm University in the digital block have been revised every semester. We still change the task and criteria in order to meet the demands from the academy, but also to explore what is recognized as knowledge and what it is possible to assess in a formal educational setting (see, e.g., Hernwall, Insulander, Åkerfeldt, & Öhman, 2016).

Hands-On in a Multimodal Learning Environment

Making—by means of experimenting with physical electronics and robots and their ensemble of modes such as lights, sounds, and symbols—holds possibilities for meaning-making (Kress, 2010; Kress & van Leeuwen, 2006), including for those who might not be interested or not have had the possibility to get in contact with programming activities for various reasons. The makerspaces presented in this study are keen on inviting people from different backgrounds and professions with different interests and experience to learn from each other and share ideas, just as Halverson and Sheridan (2014) points out as part of making culture, no matter whether you are old or young, male or female, an artist, a teacher, or a programmer. Here, learning environments are designed to foster collaboration, to share ideas and innovation with digital as well as analogue materials, and to transform and form multimodal representations. One of many critical aspects within the maker movement is about inclusion and the demanding task to create spaces that reach individuals from different backgrounds. Even though the ambition is to include and create spaces for people from different backgrounds to meet and share ideas, there is still a question of whether this is happening and if so on what scale. Here, formal education can have an important role: to invite and create making activities inside formal education. It is also important for the academy to support and challenge the students within the TE to take on a critical approach to organizations and actors outside the academy and about the use of digital technology and learning in schools (Selwyn, 2016).

Affording Material in a Mobile Transformative Era

Learning environments are, in Finland, designed to allow teachers to interact with digital tools as easily as possible. Makerspaces at practice schools are obviously very accessible, but for didactics in a transformative era (Selander, 2017), mobile learning is a change that the making movement together with TE can make use of, even if there is no practice school available. The mobile makerspaces that are currently implemented in Finland can thus be a role model for TE development, along with the need for analyzing and making policies for not implementing programming technology per se—it must be appropriate technology (Koehler & Mishra, 2008). Another possible approach is to design a university makerspace, as in Luleå: a physical place at the university with cooperation between the makerspace and the university. Also, the "open-door" approach that Luleå practices is fruitful, but then TE must be physically close enough to the makerspace, and the makerspace must be able to embrace the often massive amount of TE students if a real meeting between TE and makerspace is to occur.

Distributed Learning

For Stockholm University, to set up the collaboration on programming activities with Väsby Makerspace was not a straightforward process, as there are both rules and policy regarding collaboration with organizations outside the academy. To collaborate with an organization outside the academy, the university is obligated to make an open inquiry to organizations that could provide the required service: a time-consuming process. A formal statement that could be shared with possible collaborators was established with a designs for learning analysis focusing on why, how, when, and what was desirable in the digital block and why this kind of learning space couldn't be provided within the academy (although it is currently happening in Luleå). Although this process was an important journey, the academy needs to find more creative and flexible ways of making new connections within and outside the academy. As Selander (2017) points out, learning in our time is distributed, meaning that information is not isolated to one organization or person; instead, it is distributed and accessible from many different resources, organizations, and individuals.

Discussion

Programming and computational thinking in the Nordic countries is currently highly debated, and school laws states that educational practices should be based on research and proven experience. Programming in the 21st-century school setting is still new. Consequently, there is a lack of research on teaching and learning of programming in primary education and so also in TE. Voices are raised about the importance of digital competence of TE educators.

Makerspace and Formal TE

The maker movement is more about learning and less about education, say Halverson and Sheridan (2014), and according to Lindstrom et al. (2017) makerspaces must provide makers with a self-sense to empower them to shape the world. This by no means contradicts TE; instead, TE in the Nordic countries highlights "lifelong learning" and learning for life rather than for school. Still, TE does not match current needs of today's digitalized school. Halverson and Sheridan (2014) mean that formal education with its institutional frames might hinder the creativity, innovation, and participation that the maker movement is built upon, but our three cases indicate that it does not have to hinder creativity when framing the making by, for example, an assignment or even by grades. However, these are demanding tasks that need further discussion and research. The settings—formal and informal—in this study are to create a "space" for discussions on for example the new curriculum and the concept of programming at school, especially when people from different backgrounds and professions meet and make.

Makerspace Environments Implemented in TE

Since Nordic TE cannot provide the much-needed education of teachers and teacher students before programming is implemented in the curriculum, innovative strategies need to be found. In, for example, England, commercial companies have played a large role in providing professional development for teachers, something that could happen in the Nordic countries as well. Another possibility is to take advantage of experience and knowledge that are found within the maker movement. The three case studies have illustrated how this implementation can be made in four different didactic designs: (a) TE students can go to any makerspace to practice programming; (b) TE students, teachers, and principals can be invited to a makerspace for making and discussions; (c) mobile makerspaces can be designed at practice schools and used by TE students; and (d) makerspaces can be built up at the university.

Interface Challenges and Possibilities

In Finland and Sweden most teachers, especially those teaching mathematics, crafts, and technology, will need to be able to teach programming; thus, this subject must also be taught in TE. We believe that many TE institutions do not have the competencies or the resources for this transformation. To collaborate with communities such as makerspaces that are active nationally and can play a vital role in supporting the introduction of programming and other digital work in formal education can be fruitful. Programming taught in the interface between makerspaces and formal TE could be one way to meet the demands for teachers' digital competence. Teachers' digital competence can be developed by combining formal and makerspace activities for increased knowledge about how to use and design programming activities. We argue that TE educators as well as TE students can be inspired and learn from the organizers and instructors at the makerspaces and vice versa. We see makerspace as one of many learning spaces in which to collaborate and make meaningful digital activities, such as programming. However, the academy must be more creative in establishing these collaborations if they shall have a chance to meet the demands for digital competence as one of eight key competences (EC, 2006). Also, we believe that makerspace environments can gain by being informed about school curriculum and adjusting their operation to embrace TE educators, TE students, teachers, and pupils with an urge and need to design didactically for programming.

Conclusion

Unlike earlier research on programming, this article is created in the intersection between computer science and education, which means the results can be valuable for different faculty and areas. This article investigates didactics in and across educational settings, which is important as the landscape of education is undergoing changes in terms of time and place, as well as who is supposed to organize education (Selander, 2017). We need to broaden our perception in higher education about how we can design and arrange learning spaces between organizations and within the academy. There is a need for developing teaching methods and assessment tools in education to meet the demands on students to develop 21st-century skills, especially since many in-service and preservice teachers lack experience and knowledge of, for example, programming. One key factor, among others, to transform education is to start with TE. This article present experiences of such a transformation. It also reveals the need and suggestions for more experimental, empirical research on the meeting between makerspaces and TE.

Author Notes

Dr. Susanne Kjällander is a senior lecturer and a post doc at the Department for Child- and Youth Studies at Stockholm University. Her research interest is the digitalisation of education in preschool and in school with questions about digital competence, digital literacy and teachers' designs for learning in digital environments as well as children's and student's learning, exploration and challenges in the digital interface. Please address correspondence regarding this article to Susanne Kjällander, PhD, Senior Lecturer, Department of Child and Youth Studies/Section for Early Childhood Education, Stockholm University, Frescati Hagväg 16B, 114 19 Stockholm, Sweden. E-mail: susanne.kjallander@buv.su.se

Dr. Anna Åkerfeldt is a senior lecturer at the Department for Child- and Youth Studies at Stockholm University. Her research interest is learning, teaching and assessment in ubiquitous learning environments and how technologies challenge the understanding of these concepts and also the relationships between them.

Dr. Linda Mannila is a senior lecturer at Åbo Academy/Linköping University. Her research interest is in digitization and digital skills, everything from programming and digital creation as part of general education to issues around equality, inclusion, integrity and security in a society that is characterized by digitalisation and robotization.

Prof. Peter Parnes is a professor of Pervasive and Mobile Computing at Luleå University of Technology. His research interests include how to get young persons interested in technology, gender issues related to CS, novel user interfaces and learning in general on all educational levels.

ORCID

Susanne Kjällander http://orcid.org/0000-0002-9333-8910
Anna Åkerfeldt http://orcid.org/0000-0002-5101-7369
Peter Parnes http://orcid.org/0000-0002-4279-5396

References

Agency by Design. (2015). *Maker-centered learning and the development of self: Preliminary findings of the Agency by Design project*. Cambridge, MA: Harvard Graduate School of Education.

Balanskat, A., & Engelhardt, K. (2015). *Computing our future—Computer programming and coding. Priorities, school curricula and initiatives across Europe*. Brussels, Belgium: European Schoolnet,

Barab, S., Squire, K., & Barab, S. A. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, *13*(1), 1–14. doi:10.1207/s15327809jls1301_1.

Basu, S., Biswas, G., Sengupta, P., Dickes, A., Kinnebrew, J. S., & Clark, D. (2016). Identifying middle school students' challenges in computational thinking-based science learning. *Research and Practice in Technology Enhanced Learning*, *11*, 13. doi:10.1186/s41039-016-0036-2.

Borthwick, A. C., & Hansen, R. (2017). Digital literacy in teacher education: Are teacher educators competent? *Journal of Digital Learning in Teacher Education*, *33*(2), 46–48. doi:10.1080/21532974.2017.1291249.

Björk, L.-E. (1983). Datorers intåg i svensk skola. *Nämnaren*, *1*, 32.

Bocconi, S., & Chioccariello, A. (2016). *Developing computational thinking in compulsory education*. Luxembourg: Publications Office of the European Union, 2016, PDF ISBN 978-92-79-64442-9 ISSN 1831-9424 doi:10.2791/792158

Csizmadia, A., Curzon, P., Dorling, M., Humphreys, S., Ng, T., Selby, C., & Woollard, J. (2015). *Computational thinking: A guide for teachers*. (Available at: http://community.Computingatschool.org.uk/resources/2324). Unpublished report.

Eglash, R., Gilbert, J. E., & Foster, E. (2013). Broadening participation toward culturally responsive computing education improving academic success and social development by merging computational thinking with cultural practices. *Communications of the ACM*, *56*(7), 33–36. doi:10.1145/2483852.2483864.

European Commission. (2006). Recommendation of the European Parliament and the Council of 18 December 2006 on key competencies for lifelong learning. Brussels. *Official Journal of the European Union*, *30*(12), 2006.

Evens, M., Larmuseau, C., Dewaele, K., Van Craesbeek, L., Elen, J., & Depaepe, F. (2017). The effects of a systematically designed online learning environment on preservice teachers' professional knowledge. *Journal of Digital Learning in Teacher Education*, *33*(3), 103–113. doi:10.1080/21532974.2017.1314779.

Facer, K. (2011). Learning futures: Education, technology and social change. Taylor & Francis.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Pea Source: Educational Researcher*, *42*(1), 38–43.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. Harvard Educational Review, *84*(4), 495–504.

Heintz, F., Mannila, L., Nygårds, K., Parnes, P., & Regnell, B. (2015). Computing at school in Sweden—Experiences from introducing computer science within existing subjects. 8th International Conference on Informatics in Schools: Situation, Evolution, and Perspectives in Informatics in Schools. *Curricula, Competences, and Competitions/Lecture Notes in Computer Science and General Issues*, *9378*, 118–130. doi:10.1007/978-3-319-25396-1_11.

Henderson, P. B. (2009). Ubiquitous computational thinking. *Computer*, *42*(10), 100–102. doi:10.1109/MC.2009.334.

Hernwall, P., Insulander, E., Åkerfeldt, A., & Öhman, L. (2016). Bedömning av multimodala elevarbeten—Lärares uppfattning om bedömning. In K. Nygårds & T. Raymond (Eds.), *Navigera i den digitala samtiden*. Lärarförlaget, Stockholm.

Herring, M., Thomas, T., & Redmond, P. (2014). Special editorial: Technology leadership for preparing tomorrow's teachers to use technology. *Journal of Digital Learning in Teacher Education*, *30*(3), 76–80. doi:10.1080/21532974.2014.891875.

Informatics Europe and ACM Europe. (2013). *Informatics in education: Europe cannot afford to miss the boat*. Report of the Joint Informatics Europe & ACM Europe Working Group on Informatics Education. Michael Gove, UK, Education Secretary, 11 January 2012. http://bit.ly/w0FNvWhttp://www.informatics-europe.org/images/documents/informatics-education-acm-ie.pdf

Jewitt, C. (Eds.). (2009). *The Routledge handbook of multimodal analysis*. London, UK: Routledge.

Jun, S., Han, S., Kim, H., & Lee, W. (2014). Assessing the computational literacy of elementary students on a national level in Korea. *Educational Assessment, Evaluation and Accountability*, *26*(4), 319–332. doi:10.1007/s11092-013-9185-7.

Kafai, Y. B. (2016). From computational thinking to computational participation in K–12 education. *Communications of the ACM*, *59*(8), 26–27. doi:10.1145/2955114.

Kjällander, S. (2016). *Digitala lärplattor och didaktisk design i förskolan*. Uppsala, Sweden: Uppsala Vård & Bildning. www.uppsala.se.

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3–29). New York, NY: Routledge.

Kress, G. R. (2010). *Multimodality: A social semiotic approach to contemporary communication*. London, UK: Routledge.
Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the science classroom*. New York, NY: Continuum.
Kress, G., & van Leeuwen, T. (2006). *Reading images: The grammar of visual design* (2nd ed.). London, UK: Routledge.
Krumsvik, R. J. (2011). Digital competence in the Norwegian teacher education and schools. *Högre utbildning*, *1*(1), 39–51.
Lindstrom, D., Thompson, A., & Schmidt-Crawford, D. (2017). The maker movement: Democratizing STEM education and empowering learners to shape their world. *Journal of Digital Learning in Teacher Education*, *33*(3), 89–90. doi:10.1080/21532974.2017.1316153.
Mannila, L., Dagiene, V., Demo, B., Grgurina, N., Mirolo, C., Rolandsson, L., & Settle, A. (2014). Computational thinking in K–9 education. *ITiCSE '14, Proceedings of the 2014 Conference on Innovation & Technology in Computer Science Education*, June 23-25, 2014, Uppsala, Sweden. ISBN: 978-1-4503-3406-8, 1–29. doi: 10.1145/2713609.2713610
Newhouse, C. P., Cooper, M., & Pagram, J. (2015). Bring your own digital device in teacher education. *Journal of Digital Learning in Teacher Education*, *31*(2), 64–72. doi:10.1080/21532974.2015.1011292.
Niederhauser, D. S., & Schrum, L. (2016). Enacting STEM education for digital age learners: The "maker" movement goes to school. *International Association for Development of the Information Society.* International Association for Development of the Information Society, Paper presented at the International Association for Development of the Information Society (IADIS) International Conference on Cognition and Exploratory Learning in the Digital Age (CELDA) (13th, Mannheim, Germany, Oct 28-30, 2016)
Norwegian Ministry of Education and Research. (2012). Meld. St. 23 (2012–2013). Digital agenda for Norway—Meld. St. 23 (2012–2013) Report to the Storting (white paper).
Organization for Economic Cooperation and Development. (2015). *Students, computers and learning: Making the connection*. PISA report. Retrieved from http://www.oecd.org/edu/students-computers-and-learning-9789264239555-en.htm.
Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic books.
Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan*, *95*(3), 22–27. doi:10.1177/003172171309500306.
Rolandsson, L. (2015). *Programmed or not. A study about programming teachers' beliefs and intentions in relation to curriculum*. KTH, School of Education and Communication in Engineering Science. URN: urn:nbn:se:kth:diva-160724 ISBN: 978-91-7595-463-9 (tryckt) OAI: oai: DiVA.org:kth-160724 DiVA: diva2:791197
Rolandsson, L., & Skogh, I.-B. (2014). Programming in school: Look back to move forward. *ACM Transactions on Computing Education*, *14*(2), araticle 12. doi:10.1145/2602487.
Sáez López, J. M., González, M. R., & Cano, E. V. (2016). Visual programming languages integrated across the curriculum in elementary school: A two year case study using "Scratch" in five schools. *Computers & Education*, *97*, 129–141. doi:10.1016/j.compedu.2016.03.003.
Selander, S., & Kress, G. R. (2010). *Design för lärande: Ett multimodalt perspektiv.* Stockholm, Sweden: Norstedt.
Selander, S. (2017). *Didaktiken efter Vygotskij. Design för lärande*. Stockholm, Sweden: Liber.
Selwyn, N. (2016). *Is technology good for education*? Cambridge, UK: Polity Press.
Skolverket. (2016). *Redovisning av uppdraget om att föreslå nationella IT-strategier för skolväsendet.* Dnr U2015/04666/S. Stockholm, Sweden: Utbildningsdepartementet. http://www.regeringen.se/4a80e6/contentassets/a22b7decc51047a790f68d63c64920cb/uppdrag-till-skolverket-att-foresla-nationella-it-strategier-for-skolvasendet.pdf
Skolverket. (2017). *Få syn på digitaliseringen på grundskolenivå.* Kommentarmaterial. ISBN978-913832713-5. https://www.skolverket.se/publikationer?id=3783
Swinkels, M. F. J., Koopman, M., & Beijaard, D. (2013). Student teachers' development of learning-focused conceptions. *Teaching and Teacher Education*, *34*, 26–37. doi:10.1016/j.tate.2013.03.003.
The Royal Society. (2012). *Shut down or restart. The way forward for computing in UK schools*. Excellence in Science. The Royal Academy of Engineering. London, UK: The Royal Society. https://royalsociety.org/~/media/education/computing-in-schools/2012-01-12-computing-in-schools.pdf
Tømte, C., Kårstein, A., & Olsen, D. S. (2013). *IKT i lærerutdanningen: På vei mot profesjonsfaglig digital kompetanse*? NIFU rapport; 2013–20. NIFU. Oslo, Norway: Nordisk institutt for studier av innovasjon, forskning og utdanning. http://hdl.handle.net/11250/280429
White House. (2016). *Computer science for all*. Retrieved from https://obamawhitehouse.archives.gov/blog/2016/01/30/computer-science-all
Wing, J. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–36. doi:10.1145/1118178.1118215.
Wing, J. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society A*, *366*, 3717–3725. doi:10.1098/rsta.2008.0118.