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Kumpulainen, Kristiina

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Chapter 13

The Transformative Potential of School-based Makerspaces

Novel Designs in Educational Practice

Kristiina Kumpulainen and Anu Kajamaa

Technology-rich creative learning environments, often referred to as makerspaces, are attracting increased attention in education as mediators of novel approaches to innovative design and learning. Despite their growing popularity, makerspaces present an understudied educational phenomenon. By drawing on a body of empirical research on makerspaces in a Finnish school, our chapter will offer significant insights into understanding the potential and tensions of school-based makerspaces for student-driven creative learning and educational change.

Introduction

Lately, there has been an increased educational interest in "makerspaces" as potential sites for addressing the many demands surrounding learning and education in the knowledge society (Erstad et al., 2016). The Maker Movement and the broader "do-it-yourself" (DIY) culture celebrates hands-on innovation, creativity, personal fulfilment and community engagement across a wide array of genres, including crafts, robotics and computing (Peppler, Halverson, & Kafai, 2016). Makerspaces prescribe learner-centred pedagogies in which students can work on personally and/or collectively meaningful design projects, which supports interest-driven engagement and induces the emergence of student and teacher agency (Kumpulainen, Kajamaa, & Rajala, 2018, 2019). It is also considered that these technologically rich creative and participatory spaces offer a powerful context for students' agency, persistence, creative problem-solving and digital literacy in science, technology, engineering, arts and mathematics (STEAM) learning. Further, they provide arenas for

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utilising 21st century skills that are important for workforce development and overall functioning in the contemporary knowledge society (Peppler et al., 2016).

At the same time, emerging research suggests that makerspaces bring with them considerable tension when integrated into the educational practices of a school, creating both opportunities and obstacles for student-centred, participatory and creative learning (Kumpulainen et al., 2018, 2019). School-based makerspaces have also been criticised for their narrowly defined goals and culturally biased activities and, thus, for failing to attract and engage the broader population of young people (Peppler et al., 2016). In addition, researchers have warned about the wishful thinking that every child is a hacker and the erroneous dichotomisation of abstract thinking and play and further caution about a general ethos of more "doing" and less "thinking and reflection" in makerspaces (Blikstein & Worsley, 2016). How makerspaces contribute to new mindsets for innovative designs and educational practices is still an unexplored question.

In this chapter, we argue that in order to understand the opportunities and challenges of novel educational designs for learning and education, such as makerspaces, it is important to investigate how students and teachers participate and interact in makerspaces, as this information can shed light on the varied – and often contradictory – institutional and practice-related opportunities and constraints for implementing novel educational designs in practice. We address such issues in our chapter by drawing on a body of empirical research about longitudinal investigations into the interactional engagement of students (aged 9 to 12 years) and their teachers in a Finnish school that had recently introduced a novel design and making environment, the FUSE Studio, into its curriculum. The FUSE Studio comprises a choice-based digital infrastructure for students' creative activities, offering students opportunities to engage in STEAM design projects using a range of digital tools such as electronics, laser cutters and 3D printers (Stevens & Jona, 2017). In our chapter, we ask the following questions: How does the FUSE Studio, as a novel educational design, interact and come into tension with the more established educational practices of the school? What can we learn about the transformative potential of the FUSE Studio for student-centred, creative learning and educational change?

Conceptually, our work is grounded on sociocultural theorising (Vygotsky, 1987; Hedegaard & Fleer, 2008). From this perspective, we perceive the development and application of novel

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educational designs in education as culturally and institutionally situated and shaped. Further, we hold that students' and their teachers' participation in and experiences of institutional activities are shaped by their personal motive orientations and by the demands and history of the sociocultural setting. On this basis, we regard the students and their teachers as active participants who make sense of and influence the practices and learning opportunities in makerspaces while trying to accommodate their personal motives at the intersection of the novel makerspace and the more established institutional practices and demands of the school (Kumpulainen et al., 2019).

Our chapter offers insights into understanding how the innovative educational design of the FUSE Studio as one form of a makerspace interacts with and, at times, transforms existing school practices towards student-centred creative learning. Our chapter also provides useful information about implementing makerspaces in schools and discusses how teachers make sense of and adapt their work in relation to makerspaces. In addition, our work informs the future educational design of makerspaces for the advancement of students' 21st century skills and STEAM learning opportunities.

Study Overview

Our research stems from a Finnish city-run comprehensive primary school with 535 students and 28 teachers. Like any other school in Finland, this school follows the national core curriculum, which is defined locally. The local curriculum of the school strives for student-centredness and stresses design learning, which is targeted at enhancing students' creative problem-solving skills across the curriculum. As a response to the new curriculum requirements, the school introduced the FUSE Studio (www.fusestudio.net) as part of its elective courses in the autumn of 2016.

The education system in Finland has recently undergone a national curriculum reform with the introduction of new curriculum content, pedagogical approaches and learning environments. The new national core curriculum for the education of 7-to 16-year-olds emphasises the development of students' transversal competencies, including digital competencies, critical thinking skills and learning-to-learn, interaction and expression, multiliteracy, working life skills and entrepreneurship as well as social participation and influence. In addition, the national core curriculum recommends learning environments and pedagogies that are based on experiential, integrated and student-centred

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learning and that model real-life inquiries and problem-solving with relevant social and material resources (Finnish National Agency for Education, 2014).

The FUSE Studio

The FUSE Studio is a choice-based digital infrastructure for STEAM learning (see Stevens & Jona, 2017). The technological infrastructure of the FUSE Studio makerspace offers students different STEAM design challenges that "level up" difficulty like video games. Each design challenge has been developed in collaboration with a team of professionals in respective fields. The design challenges are accompanied by various tools, such as computers, 3D printers and other materials (e.g. foam rubber, a marble, tape and scissors), as well as instructions on how to process the challenges. The STEAM design challenges available to students include *Spaghetti Structures*, *Jewellery Designer*, *Robot Obstacle Course*, *Keychain Customiser*, *Electric Apparel*, *Coaster Boss* and *Solar Roller*. Figure 13.1 shows a student view of the FUSE challenges on a computer screen.

Please insert Figure 13.1 here
Figure 13.1 "My Challenges" student interface of the FUSE Studio

Each FUSE challenge is designed to engage students in different STEAM topics and skill sets. The design challenges have been carefully structured to introduce students to new ideas and to support them through more complex iterations of those ideas. Based on their own interests, students can choose which design challenges they want to work on, when and with whom. They can choose to work alone or with peers. There is no formal grading or assessment by teachers. Instead, using photos, videos or other digital artefacts, students can document their completion of a challenge, and the completion unlocks the next challenge in a sequence.

Please insert Figure 13.2 here
Figure 13.2 The students and their teachers working on the STEAM design challenges in the FUSE Studio

A combination of four elements in the FUSE Studio model makes it a distinctive makerspace: (1) an interest-driven approach in which students are free to select which design challenges to pursue

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and when to move on; (2) a levelling-up structure of challenges within sequences, following the basic logic of video game design principles; (3) a focus on STEM ideas and practices with a move towards STEAM, including artistic and design considerations in the criteria by which challenges are posed and judged; and (4) a core focus on cultivating interest in STEM ideas and practices among those who are not already affiliated with them, thereby aiming to broaden access to participation in STEM learning (Stevens & Jona, 2017). The FUSE Studio model differs from more open-ended makerspaces in which students are not typically offered choices of specific design challenges; rather, the work rests on the principles of design thinking, which dictate that the design is led by the identified needs of the context and/or community in question (Hughes, Morrison, Kajamaa, & Kumpulainen, 2019). Therefore, the results gained from our research need to be situated within the specific affordances and constraints of the FUSE Studio. Further research is necessary to address the integration of other types of makerspaces as novel educational designs in school contexts.

Next, we will discuss the core findings of a research project funded by the Academy of Finland and titled, "Learning by Making: The Educational Potential of School-Based Makerspaces for Young Learners' Digital Competencies" (iMake), in which we engaged in an ethnographic investigation of the adaptation of the FUSE Studio in a Finnish school. Specifically, we draw on a number of empirical studies to look into the teachers' agentic orientations for managing educational change in Finnish schools (Rajala & Kumpulainen, 2017); the agency-structure dynamics of the students' and teachers' participation in a novel school-based makerspace (Kumpulainen et al., 2018); the teachers' roles in a novel school-based makerspace (Kajamaa, Kumpulainen, & Olkinuora, 2019); and, finally, how a school-based makerspace mediates students' funds of knowledge and knowledge creation (Kajamaa, Kumpulainen, & Rajala, 2018).

The Transformative Potential of the FUSE Studio Makerspace for Student-centred Creative Practice

Our research findings provide evidence of student-driven creative STEAM practices in the FUSE Studio makerspace. Our studies show how the students creatively designed and utilised a constellation of materials and conceptual tools available in the FUSE Studio to pursue varied interests, build on each other's expertise and exercise creativity and agency (Kumpulainen et al., 2018, 2019). Many of the students and student groups creatively and agentively progressed with the FUSE Studio design challenges when interacting with various materials as well as with one another

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and their teachers. Many of the students found the design challenges intriguing and personally meaningful, and their engagement in design and making seemingly fulfilled their interests. In these cases, the makerspace environment successfully mediated the students' opportunities to draw on their personal "out-of-school" funds of knowledge to further their STEAM design and making activities and knowledge creation (Kajamaa et al., 2018).

Examples of student-driven creative resolutions included situations in which the students' work was first initiated by a FUSE design challenge; however, as their work progressed, they started to follow their own ideas and ways of working, which led to joint creative decision-making and products/end results. In these situations, it was important for the teachers to creatively and flexibly interpret the design challenges of the FUSE Studio not by focusing on the design of a specific, predefined object but rather concentrating on designs and processes that students found meaningful and engaging (Kajamaa et al., 2018; Kumpulainen et al., 2018, 2019).

When the FUSE design challenges resonated with students' interests, they worked on them enthusiastically and persistently, even when confronting challenges. In these cases, the students usually went beyond the instructions and demands of the FUSE Studio and of the teacher, generating new ideas and initiatives (Kumpulainen et al., 2018, 2019) and, at times, transforming the expected or customary practice. These situations represent "expansive learning experiences" for the students and resonate with the authentic making and design activities more typically found outside schools and in professional communities. For instance, when two students worked on a FUSE design challenge called *Spaghetti Structures*, they used several types of spaghetti and marshmallows to design and build large constructions. The students found the challenge of *Spaghetti Structures* so compelling that they simply forgot about the instructions and the time constraints of the school schedule and were instead driven by their collective motive to create something new (Kumpulainen et al., 2019).

One of our recent studies focused on the role of the teacher in the FUSE Studio makerspace. We were particularly interested in interactive situations in which the teacher(s) recognised the students' initiative and creative contributions and invited the students to reason out and explain them (Kajamaa et al., 2019). In these situations, the teachers also tried to balance and/or "glue together" the students' interests and ideas. This often helped the students to carry out their design work and

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overcome the difficulties associated with the instructions or lack of content knowledge that was required for pursuing a STEAM design challenge. The teachers also supported the students to find and/or use different materials and tools required for the design challenges (e.g. Tinkercad software, foam rubber, a marble, tape and scissors). Moreover, the teachers' interactive orchestration created opportunities for the students' relational engagement and expertise to develop (Kajamaa et al., 2019). In these situations, expertise became porous, flowing between the students and their teachers.

Further, we captured creative and agentive actions in teacher–student interactions (Kumpulainen et al., 2018, 2019). In these situations, the teachers typically attempted to support the students' creative design work based on the students' expertise and knowledge. In these interactive episodes, the teachers explored the students' existing knowledge and encouraged them to compare and test ideas as well as to identify conceptual or material resources for their design work and reasoning (Kajamaa et al., 2019). In some cases, the teachers and students jointly created an interactional space in which the students were able to deviate from the original rules and instructions of the FUSE Studio makerspace. This usually led to the creation of something new, such as a design that exceeded or expanded upon the original challenge criteria. For instance, instead of designing an earring as suggested by the FUSE Studio, the students designed a ring for a finger. In another situation, students used alternative software for their game design. Overall, these episodes were fairly rare in the data, but since such creative interactions are at the core of the makerspaces, we regard them as being important to document.

Tensions and Challenges of School-based Makerspaces

Even though makerspaces hold the potential to serve various students and their interests (Peppler et al., 2016), our research also makes visible how the students' participation in the FUSE Studio makerspace was not always straightforward and involved tensions and discontinuities. Moreover, there were students who did not find the design activities motivating, and these students demonstrated behaviour that required disciplinary actions (Kajamaa et al., 2019). Often in such cases, the more traditional teacher-centred practices superseded the novel student-driven creative practice (Kumpulainen et al., 2018, 2019). In fact, in our research dealing with the teachers' roles and intervention strategies in the FUSE Studio makerspace, the most common strategy applied by

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the teachers turned out to be authoritarian in nature (Kajamaa et al., 2018). In authoritative interactions, the teacher took charge of the cognitive work, typically dominating and/or controlling the students' learning activity. Often, this also meant that the teacher would not involve the students in problem-solving but rather would instruct them step-by-step towards a resolution. Sometimes the teacher even solved the FUSE design challenge on the students' behalf (Kajamaa et al., 2019).

The students themselves also frequently reinforced the traditional teacher-centred practice by turning to the teacher when they faced an obstacle or wanted to demonstrate their progress and/or outcomes (Kumpulainen et al., 2018, 2019). Our research shows that even though teachers took into account the students' initiatives and creative contributions, they also very often orchestrated the selection and provision of the materials for the students. This is a finding that contradicts the makerspace ideology, which underscores students' ownership over their learning activities by, for instance, being responsible for their materials and workspaces. These findings also suggest how, in an institution such as a school, it is typical that participants will draw on their customary ways of working in order to maintain stability, create coherence and address the complex realities of their everyday lives (Engeström, 2007).

Our research also suggests that the potential of the FUSE Studio to enhance student-centred creative learning is compromised if the teachers do not understand or appreciate the purpose and meaning of new designs for learning and education. Our interviews with the Finnish teachers in the school that introduced the FUSE Studio reveal that the teachers displayed different interpretations and orientations – namely, practical-evaluative, reproductive, critical-projective and creative-projective orientations – to manage and utilise the novel educational design in their practices (Rajala & Kumpulainen, 2017). The practical-evaluative orientation considered the practical realities of the teachers' strategies in relation to the new educational design and its use in practice. The reproductive orientation considered how the novel educational design of the makerspace could fit within the existing educational practices valued by the teacher. The critical-projective orientation displayed the teachers' future-orientated and transformative agency. In these orientations, the teachers identified the potential of the FUSE Studio makerspace for transforming their own educational practice and students' learning opportunities (Rajala & Kumpulainen, 2017).

Discussion

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Our ongoing research makes visible how makerspaces – in our case, the FUSE Studio – can have the transformative power to develop existing educational practices in schools towards creative student-centred STEAM engagement and learning. Our work shows how makerspaces as novel educational designs challenge traditional educational practices, including teacher and student roles and positions. In this context, students and their teachers continuously encounter diverse motives and demands that they need to personally and collectively navigate and negotiate. Adding to the complexity, the learning process of students can never be fully preplanned in makerspaces; thus, both teachers and students need to be able to withstand uncertainty. Makerspaces ask both students and teachers to adopt novel mindsets to accommodate a variety of positions, skills and competencies intertwined into creative learning.

Furthermore, integrating makerspaces in schools requires rethinking how time is organised for students and teachers in these spaces. Attention also needs to be given to the nature of and overall pedagogy behind makerspaces. In particular, consideration needs to be given to considering whether a makerspace should be integrated into the school's core curriculum or offered as an elective or after-school activity independent of the core curriculum. The educational goals of makerspaces need consideration as well, and the nature of design challenges in makerspaces deserves further attention. Based on our research, it seems that students benefit the most if the design challenges exhibit variability, from specific to more open-ended activities. More structured design challenges may create an off-ramp to real making and support students as they learn to use advanced technologies for their design activities; however, it is important that maker challenges resonate with diverse students' interests and that these ultimately lead to their engaging in authentic design and making. Ideally, makerspaces would link students' personal interests to community-relevant problem-solving and active citizenship (Marsh, Arnseth, & Kumpulainen, 2018).

In order for teachers to develop and implement the new designs and learning opportunities advocated by makerspaces, they should increasingly exercise their professional agency and reflexive thinking to find a balance between old and new ways of working (Rajala & Kumpulainen, 2017; Kumpulainen et al., 2018). Moreover, such novel learning environments call for teachers to create flexible and more reciprocal ways of working with students and with one another. In sum, managing the opportunities and demands associated with makerspaces in schools requires constant efforts, from both the students and the teachers. Novel learning environments ask for institutional

considerations about the timing and structure of schooling. We can conclude that the transformative potential of makerspaces requires a continuous process of collective creativity and learning at the level of teachers, students and institutions before such novel designs can make a sustained change to educational practice.

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