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A DIGITAL LEARNING ENVIRONMENT MEDIATING STUDENTS' FUNDS OF KNOWLEDGE AND KNOWLEDGE CREATION

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Abstract

Despite the growing importance and popularity of new digitally enhanced making and design environments, students' knowledge creation is still a fairly unexplored issue within these contexts. To address this research gap, we have drawn on empirical case study data from a public school that is implementing a novel making and design environment called the FUSE Studio. Our data comprise 111 hours of video records of 9–12-year-old students' (N = 94) making and design activities collected during one semester. Drawing from sociocultural and cultural-historical theorizing with a specific focus on the concepts of funds of knowledge and knowledge creation, we ask: 1) How are students' funds of knowledge manifested in the FUSE Studio? 2) How do students' funds of knowledge mediate their knowledge creation activity? "Funds of knowledge" refers to a student's multiple cultural resources that stem from their life worlds in and out of school. Our findings indicate that students' knowledge creation includes vertical knowledge maintenance, horizontal knowledge breaking, and knowledge expansion. The latter involves a tension-laden socio-materially mediated process that opens up opportunities for the creation of innovative solutions and expansion of a student's existing funds of knowledge.

Keywords
funds of knowledge, knowledge creation, digital, learning environment, student

Introduction

Digital learning tools and technologically enhanced learning environments have aroused recent educational interest, but their implementation in educational practices is often difficult and by and large does not benefit young people's learning (Leander, Phillips, & Taylor, 2010). Furthermore, it has been claimed that formal education has been failing to take into sufficient account each student's multiple cultural resources, referred to as their "funds of knowledge," that stem from their life worlds in and out of school (e.g., Gonzales, Moll, & Amanti, 2005; Kumpulainen & Lipponen, 2010). Building more coherence among a student's funds of knowledge across contexts can support the development of that student's learning, identity, and creativity (Honey & Kanter, 2013; Kumpulainen, 2017; Rajala et al., 2016). An example of such efforts to build coherence is studies that have incorporated new online spaces and digital tools to support meaning-making where children and young people's informal and formal identities, interests, and discourses can intersect (Erstad, 2014; Kumpulainen & Mikkola, 2014; Lantz-Andersson, Vigmo, & Bowen, 2013; Vasbø, Silseth, & Erstad, 2014; Vigmo & Lantz-Andersson, 2014). In addition, fostering robust disciplinary learning has motivated the development of pedagogical approaches to connect student learning across contexts in science (Engle, 2006; Scott, Mortimer, & Ametller, 2011), language (Dyson, 1993; Wiseman, 2011; Wong, Chin, Tan, & Liu, 2010), and mathematics (Cribbs & Linder, 2013) education.

A recent response to this need in educational settings has been the establishment of technology-enhanced making and design environments, often referred to as makerspaces. Sheridan et al. (2014) defined makerspaces as comprising participants with different backgrounds and experiences who work individually or jointly with varied artifacts, technologies, and media – both more traditional and novel spaces, but one commonality is that these spaces all involve design and making, developing an idea and constructing it into a physical or digital form. However, students' knowledge creation within makerspaces is still a vastly unexplored issue. In this study, we address this research gap and investigate students' knowledge creation in a design and making environment situated in a public school (in Finland) that has recently undergone major curricular reform and introduced a student--centered digital makerspace, called the FUSE Studio, used as part of its elective courses.

Following sociocultural and cultural-historical theorizing, we view knowledge creation as a non-linear process, always embedded in practices and mediated by language and tools in the social activity of students and teachers (Paavola, Lipponen, & Hakkarainen, 2004). Our study is based on the Vygotskyan idea of conceptual (signs, language) and material (artifact/tool) mediation of human action (Vygotsky, 1978). We stress tension, questions, and questioning as important mediators, mediating a student's interaction, innovative learning, and knowledge advancement (Engeström, 1999; Engeström, Engeström, & Suntio, 2002). Aiming to transcend the binaries between formal and informal learning environments (e.g., Engeström, 2009; Gutiérrez, 2008; Gutiérrez & Rogoff, 2003; Kumpulainen & Erstad, 2017; Marsh, 2003), we have applied a funds of knowledge approach to conceptualize how students draw upon and use the bodies of knowledge and skills that they develop in social interaction in their everyday activities to meet their needs in their particular sociocultural circumstances (Gonzales et al., 2005).

Previous studies applying a funds of knowledge approach have largely focused on promoting inclusive educational practices for underrepresented students, with ethnography being conducted by teachers in students' homes and neighborhoods and within typical classroom settings (e.g., Barton & Tan, 2009; Moll, Amanti, Neff, & Gonzales, 1992; Vélez-Ibáñez & Greenberg, 1992). Recent research in regular classrooms has shown that the ways in which teachers interact with students play a crucial role in mediating students' opportunities to draw upon their funds of knowledge and productively connect this knowledge to academic learning (Silseth, 2018; Silseth & Erstad, 2018). Researchers have yet not examined how students' funds of knowledge are manifested in school-based technology-enhanced making and design environments. It is still inadequately understood whether and how digital learning environments, digital tools, and social interaction expand a student's funds of knowledge.

Understanding that the study context of a digital learning environment deviates from traditional funds of knowledge research, our aim is to expand the funds of knowledge approach by studying a school setting that strives for learner-centeredness and innovations in learning and teaching and is committed to following the principles of progressive inquiry in its pedagogy. The FUSE Studio was established especially for promoting learning in science, technology, engineering, arts, and mathematics (STEAM) and those 21st century skills important for workforce development and overall functioning in contemporary knowledge society (e.g., Honey & Kanter, 2013; Kumpulainen, 2017).

The FUSE Studio is an intriguing context for analyzing students' funds of knowledge as part of knowledge creation because the design and making activities conducted within this context represent a complex set of socially and materially mediated creative, student-driven practices supported by a wide range of physical and digital materials (see Kumpulainen, 2017). A core design principle of the FUSE Studio is that it is choice-based and draws on students' own interests (see Stevens et al., 2016). This principle is realized in the FUSE Studio by offering students a choice among nearly 30 integrated-STEAM making and design challenge sequences that level up like video games. Students view the gallery of challenges on the FUSE website (www.fusestudio.net) accompanied by a trailer video to attract their interest to each challenge. The FUSE Studio challenges include designing a ring tone, games, jewelry, a key chain, and a dream home. Students can choose challenges according to their interests and self-document evidence of level completion to unlock new levels of difficulty in the challenge or begin a new challenge. Although the FUSE Studio strives to encourage students to persist, they are free to change and/or quit a challenge at any time in their activity.

On this basis, we ask as our research questions: 1) How are students' funds of knowledge manifested in the FUSE Studio? 2) How do the students' funds of knowledge mediate their knowledge creation activity?

Theoretical framework: The funds of knowledge approach

To answer our research questions, we have drawn on the theoretical notions of funds of knowledge (e.g., Barton & Tan, 2009; Moll et al., 1992; Vélez-Ibáñez & Greenberg, 1992) and knowledge creation (Paavola et al., 2004).

Traditionally, the analysis of funds of knowledge has concerned teacher-driven ethnographies for the promotion of inclusive educational practices for underrepresented children living in high-poverty and ethnically diverse communities that need to improve educational opportunities and quality. These foregoing studies (Moll et al., 1992; Vélez-Ibáñez & Greenberg, 1992) have widened our understanding of the social life of the households to which the children belong, demonstrating how household- or family-specific knowledge and skills essential for members' well-being and flexible functioning in changing situations are developed. Furthermore, in these pioneering studies, teachers and researchers have developed pedagogical practices that have validated and built upon the underrepresented students' funds of knowledge with positive consequences for their learning and participation in classrooms.

During the past three decades, the funds of knowledge approach has been applied in numerous studies and pedagogical experiments aimed at developing inclusive instructional practices (e.g., Barton & Tan, 2009; Hogg, 2011; Moje et al., 2004; Rosebery, Ogonowski, DiSchino, & Warren, 2010; Zipin, 2009). In the context of school, in relying on their funds of knowledge, students draw from their cultural resources and knowledge embedded in formal school practices as well as their worlds outside of school. For example, Rosebery et al. (2010) found that designing pedagogical practices based on students' everyday sense-making in elementary school science instruction had a positive impact on the learning of the scientific concepts of thermodynamics. In the pedagogical design of the study, both everyday and scientific reasoning were made objects of inquiry and diverse forms of reasoning were invited and valued in the classroom. The study highlighted that heterogeneity is an essential component of robust conceptual learning in science. Silseth and Erstad (2018) showed that teachers also spontaneously built on students' funds of knowledge as part of their instruction. In their study of mathematics and social sciences lessons in Norwegian lower secondary school classrooms, they identified varied everyday resources that the teachers used as means to contextualize instruction. The resources included, for example, characteristics of the local community, personal issues, and knowledge from traveling abroad.

In all, funds of knowledge research shows that a teacher's awareness of their students' different funds of knowledge is crucial for multiple reasons. These include challenging established instructional practices and legitimizing and valuing students' out-of-school lives, sense-making, and learning, and, in the best cases, this results in reduced complexity of the learning situations and enhancement of positive attitudes toward learning at school (Kamberlis & Wehunt, 2012; Rajala et al., 2016; Warren et al., 2001). Specifically, the more teachers know about their students' household-specific funds of knowledge, the better they can connect instruction (e.g., the design of learning projects) to the children's life worlds, potentially leading to improved educational quality (Moll et al., 1992).

Focusing on students' diverse funds of knowledge within a classroom may also create problems and emotions difficult for teachers to deal with. Previous studies have highlighted that when invited by the teacher into the classroom students' out-of-school learning and personal interests often create tensions with official, curriculum-driven instructional practices (Gutierrez, Baquedano-López, & Tejeda, 1999; Rajala et al., 2016). To overcome these tensions, studies have called for questioning of and reflection on established instructional practices and what counts as knowledge (Gutierrez et al., 1999). To investigate such tensions and whether and how students' funds of knowledge are expanded during their design and making activity, we analyzed several forms of students' knowledge creation (Paavola et al., 2004) in the FUSE Studio.

The FUSE Studio is a technologically enhanced learning environment that provides digital tools and other material means for mediating the school and out-of-school lives of participating students. In this context, the students make their knowledge explicit in innovative processes by constructing novel solutions to the problems (challenges) in question. The participants' funds of knowledge are always based on material practices and they choose to use artifacts meaningful to them in their out-of-school learning (e.g., Gutierrez et al., 1999; Zipin, 2009). Even the solutions the students come up with are embedded in the computer program (e.g., the completion of FUSE challenges) or tangible objects (e.g., the creation of an artifact, such as a spaghetti structure); they may also come up with theoretical "conceptual artifacts," symbolic in nature enhancing learning and development (Engeström, 1999; Paavola et al., 2004; Wartofsky, 1979).

Research context

The context of our study is a city-run public school with 535 students and 28 teachers at the primary level. The school follows the new national core curriculum with novel curricular content, pedagogical approaches, and learning environments aiming at promoting students' digital and learning-to-learn skills. The national curriculum has been interpreted locally by all Finnish schools, and the school under study strives for student-centeredness and stresses design and digital learning, considering these as enhancing students' creative problem-solving skills across the curriculum. In 2016, as a response to the new curriculum requirements, the school introduced the FUSE Studio as one of its elective courses. The core ideas of the FUSE Studio are to promote young learners' STEAM learning, cultivate STEAM ideas and practices among those who are not already affiliated with them, and, by so doing, broaden access to participation in STEAM learning (Stevens & Jona, 2017), which are aims resonating well with the requirements of the new curriculum.

In the FUSE Studio, students are free to select which challenges to pursue, who to work with (or to work alone), and when to move on. The challenges level up within sequences, following the basic logic of video game design principles (e.g., Salen & Zimmerman, 2005). Each challenge is designed to engage students in different STEAM topics and skill sets. The challenges are accompanied by various tools, such as computers, 3D printers, and other materials (e.g., foam rubber, a marble, tape, and scissors, which we refer to as artifacts), as well as instructions on how to process the challenges. The assessment of a student's participation and learning does not include grading but is carried out by utilizing photos, video, or other digital artifacts and the student's own documentation. Figure 1 shows the student interface (view) of the FUSE challenges on a computer screen.

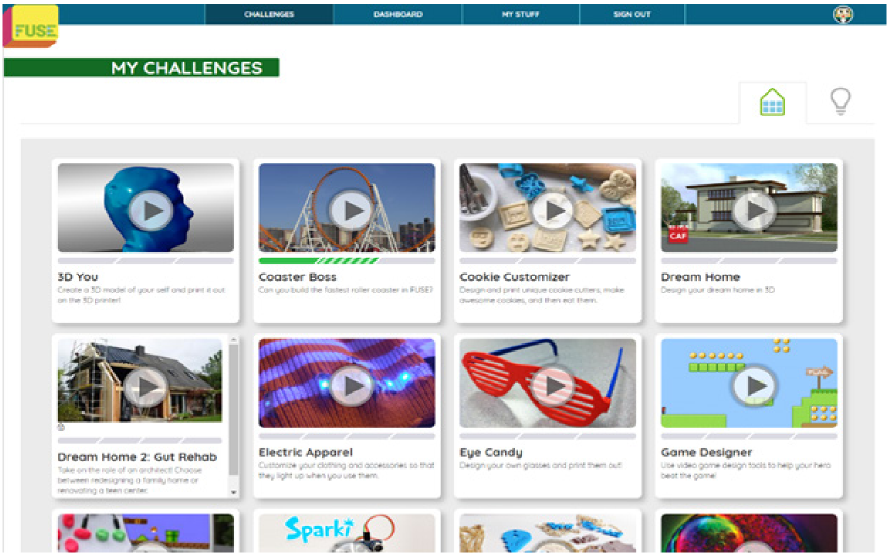

Figure 1. My Challenges student interface

In sum, the FUSE Studio provides both more structure and more support (see, e.g., Sheridan et al., 2014) for students' design and making activities than many open-ended makerspaces. It also differs from workshop-style making activities where all students typically learn how to do the same project and/or use the same tools (e.g., Fields & King, 2014; Peppler & Bender, 2013; Resnick et al., 2009). Finally, in contrast to the mentor-centric or apprenticeship-based model employed in many makerspaces, in the FUSE Studio, the teacher is defined as a facilitator who is seen as one of many resources students can draw upon. A FUSE Studio design principle is to encourage students to seek assistance from their peers or digital resources available on the website before or instead of seeking help from a teacher.

Methodology

Our primary data comprise 111 hours of transcribed video recordings and field notes about students (N = 94) aged between 9 and 12 years old and their teachers carrying out making and design activities. A video research approach (Derry et al., 2010) amplified by interaction analysis (Jordan & Henderson, 1995) was considered to serve well the foci of our research on the students' knowledge creation processes. The video data were collected intermittently over a period of one academic year in the FUSE Studio and its close surroundings by a team of researchers using three or four video cameras concurrently. The students' individual and group activities were located in three different rooms and the corridor. Thus, it was deemed necessary to have multiple video cameras recording students' design and making activities from a single session in order to collect a rich record of students' interaction processes constructed into being among students and their teachers. At times, depending on the challenge, the students also used other school spaces near the actual FUSE Studio in order to have more room for their making activities. Video cameras were also brought to those spaces to record the students' interaction processes during their making activities.

The video data reported herein come from three groups of students and their teachers who participated in the FUSE Studio elective course. Due to the elective nature of the FUSE course, the groups consisted of students from several grades. Group 1 consisted of 32 students (22 boys and 10 girls), Group 2 30 students (19 boys and 11 girls), and Group 3 32 students (19 boys and 13 girls). Each group was supported by two to four teachers and teaching assistants. At the beginning of the academic year, each group had one 45-minute FUSE session per week. Later in autumn, each session was extended to 60 minutes. Data crucial to the study was transcribed verbatim.

The video data and field notes capturing students' and teachers' social activity in the design and making environment were analyzed using interaction analysis methods (Jordan & Henderson, 1995). In this study, following such methods meant paying careful attention to the construction of an interaction on a moment-to-moment basis. It was important to understand how the ongoing interaction was constructed into being over time and how different discursive acts were built into episodes with a particular meaning. The interaction analysis approach thus enabled us to gain insights in the students' knowledge creation processes – their development, maintenance, and closure. Interaction analysis also enabled us to understand how the students' funds of knowledge and negotiations among students and teachers mediated the knowledge creation processes.

Our analytic approach can be defined as abductive, involving repeated iterations between theory and data (Van Maanen, Sørensen, & Terence, 2007). Our interaction analysis proceeded to the tracing of the main forms (or patterns) of students' knowledge creation from the depicted interaction episodes. To capture the manifestations of students' funds of knowledge related to familiar/customary patterns of activity for doing school activities, we first further analyzed the interaction episodes that took place among the students and their teachers in the FUSE Studio. In this analytical phase, we also depicted the manifestations of the students' funds of knowledge when interacting with artifacts and objects (i.e., not just with people) during

FUSE activities. When applying this type of knowledge creation pattern, the students often drew from their existing knowledge of formal schooling without questioning or reconceptualizing the FUSE challenges or the teacher's instructions. Then, we zoomed into the interaction episodes among the students that provided evidence of breaking away from their existing funds of knowledge and traditional socio-material enactments of doing school-based activities. Thereafter, to dig deeper into the students' formation of new knowledge, we analyzed those interaction episodes where students' out of school/free-time interests were recognized and taken into account (by their peers and/or a teacher) and where they reframed the activity, extending the original FUSE challenges.

Findings

Our analysis revealed three main forms of students' knowledge creation processes during their design and making activities: 1) *vertical knowledge maintenance*, 2) *horizontal knowledge breaking*, and 3) *knowledge expansion*. In the FUSE Studio, students' knowledge creation often focused on knowledge maintenance, in other words their following the structures and instructions given by the FUSE computer program and the facilitating teachers. Still, relatively often, students used their own initiative to break away from the situation creatively. In some cases, this created tensions between the students' funds of knowledge and the rules and instructions of formal schooling given to them by their teachers. This led to a tension-laden and innovative process in which student groups and sometimes also students with their teachers collectively challenged and questioned the existing funds of knowledge of formal schooling and broke or destabilized them to co-configure expanded, future-oriented knowledge. The following empirical examples illustrate how these forms of knowledge creation manifested in the students' design and making activity in the FUSE Studio. In the examples, we demonstrate the use of the analytical method applied in the analysis. All of the three types of knowledge creation appear in the examples, and examples that typically manifested in the data have been chosen for presentation.

Vignette 1: Vertical knowledge maintenance

In Vignette 1, two students, Asko and Niilo, were working on the Electric Apparel challenge. In this challenge, students are tasked to attach LEDs to a piece of felt and create a circuit using a lace, which conducts electricity. When the teacher arrived, the students proudly presented their creative interpretation of the assignment to her. In addition to connecting the circuits to illuminate the LEDs, they designed a shirt for the cat of one of the students:

Asko: *We made a really cool shirt. We made a shirt for a cat!*
Niilo: *We need to make pants another day, as we're making a shirt now.*
Teacher: *A shirt for a cat, right?*
Asko: *Yeah.*
Teacher: *Okay, Alright.*
Niilo: *That's why it's going to be a bit smaller.*
Teacher: *Okay, yeah. Alright.*
Niilo: *Here's his* (the cat's) *arms and –*
Asko: *Wait a minute, wait a minute – Oh, this is narrower than my cat's paw – This one, nooo –*
Teacher: *Okay, well were you supposed to do that – or was it that you were supposed to cut a strip of the felt and attach the LED lights to that? What did they* (the instructions) *say?*
Asko: (reading out loud) *Can you get the LED to light up? – Yes.*
Asko: *Can you get three LEDs to light up? – Yes.*
Teacher: *Yes, but what does it say about the felt?*
Asko: *Umm, I don't know.*
Teacher: *Yes, don't do anything – or that one piece of felt doesn't matter – but from now on you should always read the instructions through first and see what they say. It seems nice to make a shirt for a cat, but I don't think it said that you need to design a shirt for a cat.*

In this example, the students' activity had been initiated by the FUSE challenge, but they had also followed their own ideas and ways of working. Although the task instructions only asked the students to cut a stripe of felt and attach LEDs to it, the students used the occasion to design a cat shirt from the felt. Through the students' creative interpretation of the task instructions, more of their personal interests and knowledge became relevant to the activity. However, the teacher seemed unimpressed and directed the students' attention to the task instructions. The students read the task instructions aloud and confirmed that they had completed the official parts of the task requiring them to connect LEDs to light up. Despite the students having met the task requirements, the teacher reprimanded them for their divergence from the task instructions and encouraged them to adhere to the instructions in the future.

This interaction presents evidence of the power of the FUSE Studio to encourage the students to draw on their personal interests and knowledge while engaging with FUSE challenges. However, the episode also shows that the potential of the FUSE Studio to provide material means for mediating between school-based demands and students' funds of knowledge is compromised when teachers do not take up the new opportunities. The interaction in the episode privileges a more traditional classroom interaction through which students are expected to follow the instructions given to them by the teacher. We call this vertical maintenance of school knowledge, vertical referring to the top-down nature of the knowledge creation, based on school learning and teacher-centeredness and where student initiatives are disregarded by the teacher.

Vignette 2: Horizontal knowledge breaking

In Vignette 2, three boys were working on the Dream Home challenge in which students are tasked with designing a virtual dream home with 3D modeling software. They were sitting next to one another, working on separate laptops and each on their own individual challenge. Instead of asking for guidance from the teacher facilitating the FUSE session, as was customary when starting a new challenge, these students broke away from teacher-instructed ways of engagement and began the challenge as a group. One of the students started designing a kitchen for his dream home. Based on his personal experience and out-of-school knowledge, gained at home, he explained to his friends the kind of sink and faucet he wanted to design. He explained in detail how he was going to design a contemporary faucet with a circular shape and water flowing from each side of the circle. One of his fellow students also had out-of-school, personal experience with different types of faucets and he started to explain these to the others to imagine and design a faucet for his own dream home.

> Jere: *Hey, this wasn't good … my sink's ... this thing. This is really difficult.*
> Ville: *Try it!*
> Jere: *Oh, now I know! I'm going to make a contemporary one.*
> Max: *So, what are you doing?*
> Jere: *I'm designing my kitchen sink.*
> Max: *Show me what you're doing.*
> Jere: *This is going to be a modern one. The faucet is going to be in the middle of the sink, it'll be be a circle, and water will come out of each side.*

In this interaction episode, the three students were excited about the task at hand. In contrast to the first example, they were doing the same FUSE challenge at separate computers but as an interactive group, sharing knowledge and guiding one another. The students brought their personal experiences and knowledge (funds of knowledge), for example experiences using different types of faucets, and the others learned from these. The vignette demonstrates how these students utilized their shared knowledge about how water flows from a faucet. Then, they started to integrate their understanding of how the water flows from faucets with their everyday experiences gained in using different faucets.

As a consequence, the potential of the FUSE Studio to mediate school and out-of-school knowledge practices was effectively realized. The interaction among the students can be defined as an attempt to break away from teacher-instructed ways of engagement, actively relying on their personal funds of knowledge and interest in the learning activity. We call this horizontal breaking of school knowledge, in which horizontal refers to the bottom-up/student-driven nature of the knowledge creation, based on student-centeredness and the students' own initiative. In this case, the school-based and out-of-school knowledge interacted productively, but tension and questioning did not mediate the students' interaction, as is the case in the example of knowledge advancement in Vignette 3.

Vignette 3: Knowledge expansion

Two students were working on the Dream Home challenge and talking about the sizes of their house designs. As in Vignette 2, the students were attempting the same challenge individually, working on separate laptops, and constantly interacting with and instructing one another. One of the boys was designing a house for himself, which he considered to be a large detached house. The other boy was designing a studio apartment that he considered to be "*the biggest studio ever*." He thought that at least two people could easily live in a studio apartment that big.

In this interaction episode, the students first drew on their personal knowledge to discuss what counts as a big house and how many people could live in a house that was the size of their design. They then began moving from an individualistic orientation to a collective one. In other words, the students connected their prior, personal knowledge of house design, derived from their own family experiences, to the shared and expanded socio-cultural understanding of people's everyday lives and housing and social status, derived from their different family experiences. In our data, such a shift from an individualistic orientation to a collective one often began with tension between students' distinct funds of knowledge, which then was, one way or another, over time, overcome. In the following example, the students started arguing about what counted as a big house and questioning the other's existing understanding:

> Ville: *See, this is my bathroom. It's very big!*
> Jere: *Ha ha, it's almost the size of a door!*
> Ville: *The doors are rather small when you consider that my house is a big detached house.*
> Jere: *It's not that big a detached house if you compare it to mine. Especially as my house is a studio apartment. This might be the biggest studio ever!*
> Ville: *Mine could be a studio too... No, wait.* (counting the rooms on his fingers) *No, this is not a studio.*

In this example, we could characterize the students' knowledge creation in terms of collective knowledge expansion. It is triggered by tension that is overcome in the interaction between the students resulting in expanded opportunities for present and future action. More precisely, the tension is overcome when one of the students shifts the discussion from an individualistic tone ("*my bathroom, my house*") into envisioning the collective possibility of a future dream home, which is a studio shared by at least two people, and his fellow student then supports the idea. The expansive mode of the students' knowledge creation is sustained when one of the students, Jere, uses the knowledge he has obtained while working on his Dream Home challenge to envision future action, starting to imagine his future profession as an architect. His fellow student supports the idea. This time, the FUSE Studio provided the students with opportunities to apply knowledge in creative, innovative, and expansive (future-oriented) ways while working on the FUSE challenges. In this case, the digital learning environment of the FUSE Studio functioned as a powerful mediator between the students' funds of knowledge and learning.

Discussion and conclusions

In this study, we investigated students' knowledge creation in a public school that had recently undergone major curricular reform focused on the development of students' digital and learning-to-learn skills and that had its formal classroom learning environments extended by the introduction of a new digital making and design environment, the FUSE Studio. Our analysis provides novel findings in connecting the notion of funds of knowledge to the theoretical notion of knowledge creation. Our study goes beyond the traditional notion of funds of knowledge typically referring to a student's existing home and family-specific knowledge utilized to support inclusive educational practices in a teacher-instructed classroom context (e.g., Moll et al., 1992; Vélez-Ibáñez & Greenberg, 1992).

Our findings highlight not only the importance of students bringing their personal out-of-school funds of knowledge into the school context, but also the crucial importance of students' collective knowledge expansion by resolving the tensions that emerge when school-based learning actions and a student's personal funds of knowledge meet. We illustrated how this process may lead to the creation of unexpected and future-oriented solutions (tangible and digital objects) as well as the development of a student's theoretical "conceptual artifacts," which are symbolic in nature and enhance the student's learning and development (see also Engeström, 1999; Paavola et al., 2004; Wartofsky, 1979). Furthermore, our findings indicate that the FUSE Studio created a complex intersection (see also Barton & Tan, 2009) providing material means for mediating between the school and out-of-school knowledge of the studied students.

Previous sociocultural and cultural-historical studies have focused on the study of work and production and emphasized the crucial importance of creative practices in working with knowledge and renewing prevailing practices (e.g., Ahonen, Engeström, Virkkunen, & Malhotra, 2000; Kajamaa & Schultz, 2017). The promotion of innovative knowledge practices (such as knowledge expansion) could provide valuable lessons and guide knowledge advancement and the transformation of school contexts undergoing curricular reforms. We also acknowledge the many difficulties and tensions involved in efforts at educational change (see also Bereiter, 2002; Paavola et al., 2004) and the introduction of digital learning environments, as shown in Vignette 1. The FUSE Studio is an elective course and represents only one way of implementing novel curricular content. Still, as vignettes 2 and 3 demonstrate, it has the potential to be a promotional context for students' knowledge expansion and learning. The ways in which teachers interacted with students played a crucial role in mediating the students' opportunities to draw upon their funds of knowledge and productively connect this knowledge to their academic learning (see also Silseth, 2018; Silseth & Erstad, 2018). Our findings point to the need to research and better understand the role of the teacher in a FUSE studio and different makerspaces in general, identifying interaction processes among teachers and students that support and enhance students' knowledge creation processes.

Our analysis also advances research on the educational potential of making and design environments in school contexts. The main message to educators utilizing and developing digital learning tools and technologically enhanced learning environments is that there is a need to reflect upon and make connections among knowledge maintenance, breaking, and expansion during students' learning activity. The conscious promotion and management of a dialectical interplay among several forms of knowledge creation, which are all important in students' learning activity, is necessary and forms a current pedagogical challenge for educators. The next step would be for teachers and students to co-create shared goals and objects for future learning actions, to improve the connection between students' learning and their worlds and futures outside the school context.

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