Communications of the Association for Information Systems

Volume 48 Article 32

4-8-2021

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Recommended Citation
Halkola, E., & Kuure, L. (2021). How Teachers Participate in the Infrastructuring of an Educational Network. Communications of the Association for Information Systems, 48, pp-pp. https://doi.org/10.17705/1CAIS.04832

Communications of the Association for Information Systems

Information Systems Education DOI: 10.17705/1CAIS.04832 ISSN: 1529-3181

How Teachers Participate in the Infrastructuring of an Educational Network

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Abstract:

The evolution of Digital technologies has changed the ways in which people interact with and through technologies. Despite longstanding investment in technical and pedagogical infrastructure, schools vary greatly in the degree to which they have digitalized. New curricula in Finland have put additional pressure on education to meet the goals set for learning in the 21st century. In information systems (IS) research, digitalization increases an interest for understanding contemporary IS projects as infrastructuring. In this study, we examine how teachers as influential actors in transforming their environment participated in shaping the infrastructuring of the educational network of a Finnish city. A nexus analysis of teachers' interviews revealed three main discourses. The first discourse depicted teachers balancing between traditional and new educational solutions when aligning their pedagogy-driven practices with curriculum objectives. The second discourse concerned infrastructuring activities for establishing pedagogical ICT use successfully. The third discourse highlighted practices that teachers used to share resources as an organizational-balancing effort. The results reveal tensions between collegiality and leadership, submissive and empowered agency, and discontinuities and anticipation in ensuring continuity in infrastructuring. We discuss implications for organizing in-service training and developing local practices as contributing to infrastructuring in the educational network.

Keywords: Socio-technical System, Participation, Stakeholder Involvement, IT Infrastructure, Empirical, Societal Change

This manuscript underwent peer review. It was received 5/15/2020 and was with the authors for two months for one revision. Carina de Villiers, served as Associate Editor.

1 Introduction

The rapid evolution of digital technologies has changed the ways in which people interact with and through technologies. In the information systems (IS) field, researchers have focused on understanding contemporary IS projects that integrate large-scale technological solutions in complex information infrastructures (Hanseth, 2010). Researchers have characterized the long-term development of such large-scale efforts as infrastructuring that involves not only professional designers but varied users and designers (Star & Bowker, 2006; Pipek & Wulf, 2009; Björgvinsson, Ehn, & Hillgren, 2010, 2012a; Karasti & Baker, 2008). Infrastructuring refers to activities that practitioners perform naturally in designing their own practice environment to successfully use information technology (Pipek & Wulf, 2009).

In this study, we approach infrastructuring in the education field where teachers play a central role in contributing to change in their institutional environments. The rationale for the study arises from the pressing need to accelerate change towards pedagogically and technologically informed digitalization in schools (OECD, 2015, 2019). Although society has directed longstanding investment in developing technical infrastructure and teacher education, desired changes have not yet occurred in the teaching and learning practices on a wide scale (Yelland, 2018). In some schools, the solutions promoting digitalization and 21st-century skills have merged into their daily life, while others experience major discontinuities in relation to using technology. Technology has often remained as an add-on rather than a natural resource for learning. Researchers have noted Finnish schools to be in transition towards digitalization with the new curricula putting additional pressure on education to meet the goals set years ago in this respect (Ilomäki, Taalas & Lakkala, 2012). The controversial situation became highlighted when the coronavirus disease of 2019 (COVID-19) epidemic suddenly closed all schools in Finland and teachers had to move online in early 2020. While many teachers adopted innovative solutions to teaching students, others relied on mechanical exchange of tasks and answers. Some teachers despaired about how to handle teaching when their pupils did not physically attend class. The situation triggered teachers to actively develop pedagogical practices for technology-mediated interaction and learning that may affect life in schools even after the COVID-19 pandemic. Teachers constitute the key actors in contributing to change as they have great freedom in Finland in how they put educational policies, strategies, and the national curriculum into action at a local level.

In this study, we explore how teachers in different schools in a city in Finland understood and accounted for their participation in infrastructuring their educational network. Researchers have previously studied various actors' participation in infrastructuring in a Finnish city's educational network (Halkola & Iivari, 2014; Halkola, Iivari & Kuure, 2015). We complement these studies by analyzing teachers' infrastructuring activities in depth. We use a nexus analysis as our research strategy (Scollon & Scollon, 2004) because, with it, we can study discourses that both emerge in social action and have links to more distant discourses with societal relevance. We interviewed 12 teachers who had taken part in collaborative planning and experimenting with technology-enhanced learning in their schools in Finland to gain their perspectives as key social actors in efforts to potentially digitalize their school, the nexus of practice that we focus on in this study. In the interviews, the teachers pondered the role of technology in their daily pedagogical practices, how they coped with integrating pedagogy and technology, and what kinds of breakdowns emerged that required teachers' actions. The interviews foregrounded different degrees of agency between teachers in these matters. The interviews themselves also contributed to potential change, which nexus analysis focuses on achieving, as the teachers became aware of their role in infrastructuring related to efforts to digitalize their school.

This paper proceeds as follows: in Section 2, we provide theoretical grounding about digital technology in basic education in Finland, digital competence, and digital literacies. We also discuss research related to defining the information infrastructure (II) and infrastructuring notions. In Section 3, we describe our research method and procedures for gathering and analyzing data. In Section 4, we present our empirical results. In Section 5, we identify the results' implications and limitations, outline paths for future work, and conclude the paper.

2 Related Research

2.1 Information Infrastructure and Infrastructuring

Star and Ruhleder (1996), Star (1999), and Bowker and Star (1999) provide their well-known relational and socio-technical II characterization as evolving through locally tailored technologies as intertwined with

formal infrastructure elements. Relational to a community's local practices, a transparent, supportive infrastructure transforms in response to community evolution and adoption. IIs need to be changeable to support prevalent organizational conventions, evolving practices, and how actors use technology. When larger-scale technology influences local practices, the alignment between the local and global infrastructure elements may cause tensions. These tensions need to be resolved to allow actors to use infrastructure in a natural, convenient way (Star & Ruhleder, 1996).

Numerous independent actors, developers, and users participate in IIs' evolving, large-scale and complex socio-technical entanglements (Hanseth, 2010). In the participatory design (PD) context, for example, stakeholders' perspectives have drawn attention due to political and ethical concerns relevant in design (Star & Bowker, 2006; Neumann & Star, 1996; Karasti, 2014). Non-professional designers have also had an important role in relation to communities in PD emerging "in the wild" (Karasti & Syrjänen, 2004). Additionally, researchers have called for efforts to examine political aspects in the PD field in infrastructuring in more detail due to the increasing versatility of the conditions for user participation (Karasti, 2014).

A growing body of research on infrastructures' formation and design has discussed participatory design (PD) in terms of user participation in infrastructuring (e.g., Karasti, 2014; Bødker, Dindler, & Iversen, 2017; Björgvinsson et al., 2010, 2012a). Researchers have also considered infrastructuring a central issue for contemporary innovation, which demands that stakeholders extensively collaborate with one another over time (Björgvinsson, Ehn, & Hillgren, 2012b) and sustain relationships for design opportunities to emerge (Hillgren, Seravalli & Emilson, 2011). Researchers have also discussed the need for professionals to design potential public matters in an open-ended manner that, through infrastructuring, can become design-in-use objects for participants (Ehn, 2008).

The infrastructuring concept refers to the tentative, flexible, and open process by which actors build IIs and IIs evolve (Star & Bowker, 2006). The borders between use and design become blurred due to ongoing changes, ease of maintenance, and long-term efforts to tailor flexible and adaptable systems (Karasti & Baker, 2004; Karasti & Syrjänen, 2004). Hence, researchers have widely examined users' role in infrastructuring. Infrastructuring entails entangling and intertwining potentially controversial "a priori infrastructure activities" (i.e., selection, design, development, deployment, and enactment) with "everyday design activities in actual use" (i.e., mediation, interpretation, and articulation), and "design-in-use" activities (i.e., adaptation, appropriation, tailoring, re-design, and maintenance) (Björgvinsson et al., 2010, 2012a). The work-oriented perspective on infrastructuring suggests that users design and implement infrastructures primarily based on how they actually use technology. Researchers understand users' activities in infrastructuring as reconceptualizing one's own work in relation to existing, potential, or envisioned use of ICT tools. Practitioners have an important role in designing their own practice environment to successfully use ICT. The in-situ design activities that the users perform may relate to configuring, tailoring, or developing new conventions until they successfully use technology. End user-driven infrastructuring activities also include "resonance activities" that cover all the observations and communications related to the discontinuities of the infrastructure in a work environment (Pipek & Wulf, 2009). Moreover, end user design activities may arise from infrastructural breakdowns or from users' recognizing potential innovations and reconsidering how they use current infrastructure. Thus, various motivational forces may evoke users to reconsider practice—they entail a dependency on the invisibly supporting infrastructure and usually relate to actual or perceived infrastructure breakdowns and extrinsically or intrinsically motivated practice innovation (Pipek & Wulf, 2009; Ludwig, Pipek, & Tolmie, 2018).

Studies in the participatory computer-supported cooperative work (CSCW) field have also examined infrastructuring and collaborative design (Pipek, Karasti, & Bowker, 2017; Karasti, Pipek, & Bowker, 2018). They have approached infrastructuring as part of designing and using information technologies (Pipek & Wulf, 2009, p. 447.) The recent special issues in *Computer Supported Cooperative Work* in particular, bring to focus the processual (in-the-making) perspective and/or design-oriented engagement with IIs (Pipek et al., 2017; Karasti et al., 2018).

Researchers understand infrastructuring to extend the temporal, organizational, and societal scopes of infrastructures and diversifying collaboration arenas in design. In addition to common use, design and development activities also involve professionals from industry, formal organizational structures such as standardization bodies and authorities, and community members and citizens in informal, community-based initiatives (Pipek et al., 2017). Furthermore, recent research on infrastructuring has identified invisibility, relationality, and connectedness as the most salient dimensions of infrastructuring for analysis

(Simonsen, Karasti, & Hertzum, 2020; Karasti & Blomberg, 2018). Literature also proposes ethnography and ethnomethodology as fruitful approaches to explore IIs and infrastructuring. The former involves reflexive engagement with the research topic for recognizing the partiality of the II under study (Karasti & Blomberg, 2018), while the latter recognizes the relational ontology of the II notion combined with the infrastructuring concept that brings along a process ontology (Karasti et al., 2018).

Researchers have used the infrastructural inversion (Bowker, 1994) concept to capture infrastructure's transparent, background, and historical elements (Star & Ruhleder, 1996; Star, 2002). Infrastructural inversion entails IIs being built on an installed base (Star & Ruhleder, 1996; Hanseth, 2010) and becoming visible when they breakdown (Star & Ruhleder, 1996, pp. 5-6). In recent literature, the concept refers to tracing and foregrounding concrete infrastructural relations and connectedness (Simonsen, Karasti & Hertzum, 2020).

2.2 Teachers and the Digitalization of Schools in Finnish Basic Education

Society's digitalization in the last few decades has raised concerns in education that researchers have studied widely. However, we lack consensus about its specific educational effects (Pettersson, 2018, p. 1015). Despite the longstanding investment in equipping schools with ICT, educating teachers, andtraining teachers in service, learning environments and experiences that education can offer differ greatly (Tanhua-Piiroinen et al., 2016; Vahtivuori-Hänninen & Kynäslahti, 2016; Chaudron, Di Gioia, & Gemo, 2018, pp. 82-84; Mulari & Vilmilä, 2016; European Union, 2019). Society expects changes in education, which means teachers will need to become change agents in transforming learning approaches by drawing on various resources, which includes ICT (Publications Office of the European Union, 2019; Redecker, 2017).

UNESCO's (2011) framework for digital competency expects teachers to create educational activities that help students become collaborative, problem-solving, and creative learners with ICT's help. Digital competency will lay the foundation for students' growth towards effective citizenship and competence as workforce members. European recommendations have outlined digital competence as among the key competences for lifelong learning (Council of the European Union, 2018). According to the recommendations, digital competence involves confidence and a critical stance in using technologies for work, leisure, and communication. As Ilomäki, Kantosalo, and Lakkala (2011) suggest, digital competence entails that individuals mobilize knowledge, cognitive, and practical skills and involves social and behavioral components, such as attitudes, emotions, values, and motivations. Digital competence also constitutes a highly political term that reflects beliefs and wishes about the skills that capable citizens will need in the future (Ilomäki, Paavola, Lakkala, & Kantosalo, 2016).

Jewitt (2008, p. 255) suggests that schools need to attend to the diverse ways in which students make meaning and their literacy practices and, in particular, to acknowledge their multilingual, multimodal, and digital aspects not as isolated sets of skills and competences but as an intertextual web of contexts and media. Doing so poses a challenge in pedagogical development because the media's and technologies' pervasiveness has not necessarily led to renewed practices in the educational context, such as with literacy teaching (see also Sefton-Green, Nixon, & Erstad, 2009; Yelland, 2018, p. 849). Ilomäki et al. (2016, p. 671) propose that digital technologies should be included in a ubiquitous way in all learning and teaching. Educators should not treat it as a specific "content" that students need to learn but as a pedagogical approach across various school subjects. We can see as much in Finnish curricula where digital skills represent a transversal competence that educators should integrate in all school subjects (Finnish National Board of Education, 2014).

In Finland, there are national curricula for different educational fields. Education providers on municipal and school level put these curricula into action. The national curriculum for basic education, renewed in 2014, emphasizes the integration and dialogue between different school subjects (Finnish National Board of Education, 2014). It describes seven areas for transversal competence that involve growing knowledge, skills, values, attitudes, and will and link to subject-specific objectives: 1) thinking and learning to learn; 2) cultural competence, interaction, and expression; 3) taking care of oneself and managing daily life; 4) multiliteracy; 5) ICT competence; 6) working life competence and entrepreneurship, and 7) participation involvement and building a sustainable future (Finnish National Board of Education, 2014). As for ICT, the curriculum guides teachers to advance digitalization comprehensively in their teaching (Finnish National Board of Education, 2014).

These emphases in the curriculum and consequent requirements concerning pedagogical development have led to pressures in teachers' work considering their traditionally strong pedagogical autonomy. Through basic education's ongoing digitalization, the national curriculum expects teachers to become ICT-competent developers of their work practices and work environment and to collaborate more with their colleagues (Vangrieken, Dochy, Raes, & Kyndt, 2015). Thus, in the educational network's infrastructuring process, teachers have a central role as technology appropriators in the everyday settings and practices in their schools.

Considering the current situation in the case context that we examine in this study, national- and local-level educational bodies have launched efforts for ICT education to support schools in digitalization, such as through tailored ICT-training and digital tutoring. The European Union also provides schools with opportunities for international collaboration through project funding. An example includes the Digital Schools of Europe (DSoE) project (http://www.digitalschoolseurope.eu), which helps equip schools with ICT infrastructure by publishing best practices in ICT among participating schools, providing tailored in-service education, and offering new arenas for teachers to share ideas about using technology. The curriculum reform has also evoked vivid public discourse on in-service education targeted at strengthening teachers' ICT competence.

The Finnish Government has taken various national measures to support teachers in contributing to digitalizing schools. For example, the Finnish Government launched a peer-group mentoring program to enhance dialogue and knowledge sharing between teachers in a non-hierarchical way (Publications Office of the European Union, 2019; Geeraerts et al., 2015). This mentoring program provides active hands-on workshops, massive online open courses (MOOCs), and webinars for professionals in education. Teachers also share ideas and experiences in their own Web-based networks (Publications Office of the European Union, 2019). European countries need to invest in such in-service teacher education because challenges still prevail in promoting 21st-century skills and transforming schools into learning environments for the future.

3 Research Method

In this study, we use nexus analysis (Scollon & Scollon, 2003, 2004) as our research strategy because, with it, we can extend the research perspective from the micro level to the organizational and institutional social-analysis levels. Nexus analysis involves a view of social action as an intersection of: 1) interaction order (i.e., mutual relationships and social arrangements between social actors), 2) historical body (i.e., participants' personal histories, social identities, and roles with the action), and 3) discourses in place (i.e., the semiotic systems that emerge in situ and echo the past and anticipate the future). Scollon and Scollon (2004) developed the concept of interaction order from Goffman's (1983) work and historical body from Nishida's (1958) work. Discourses may cycle at a rapid pace as in conversational encounters or more slowly as in the media. Thus, discourses may relate to concrete situations or to spatially more distant voices in broader societal contexts (e.g., policy making related to the curriculum on the national and the local levels).

The analysis focuses on a nexus of practice—a linkage of recognizable, multiple practices that researchers also need to enter to find their zone of identification (Scollon & Scollon, 2004, p. 156). In our study context here, the nexus of practice comprises teachers' participation in infrastructuring an educational network and, more closely, their role in digitalizing their school. As for the researchers' zone of identification with this nexus of practice, the first author participated in planning and conducting participatory research activities (including the interviews) in the schools. Previous research experience in children's participation in the infrastructuring of an educational network led the author to focus on teachers' role in this area as well. The second author has studied the same field but from a humanities perspective with an interest in developing pedagogically sound digital practices for schools and teacher education.

Nexus analysis proceeds through three main activities: engaging, navigating, and changing the nexus of practice (Scollon & Scollon, 2004, pp. 9-10). First, in the engaging activity, researchers establish the social issue to study, reflect on their zone of identification with the topic, and trace the crucial social actions and participants. Second, in the navigating activity, researchers acquire and generate data and examine the most important discourses while zooming in and out the nexus of practice through the materials (Larsen & Raudaskoski, 2019; Nicolini, 2010). Third, in the changing activity, researchers take intentional steps to contribute to change in the nexus of practice in focus, or their participation may trigger

change implicitly when they become members in a community. Researchers can repeat these activities, and the activities can intertwine in many ways as researchers conduct a study (Scollon & Scollon, 2004, pp. 9-10).

Below, we describe how we proceeded through the three activities. The first author participated in all the activities below, while the second author participated in analyzing the data and interpreting the results.

In the engaging activity, we

- Identified key actors*:* we identified teachers with an influential role in infrastructuring their educational network (i.e., developing pedagogical practices related to digitalizing their schools).
- Established shared ground*:* we made contact with the local educational officials, participated in meetings with school headmasters in the educational network to introduce planned research activities, and discussed detailed plans of the study through email and in a meeting.
- Invited participants*:* we invited 12 teachers from a developer-school network in the city (basic education, grades 1 to 6) for an interview.
- Generated research data*:* we conducted interviews (that lasted from 30 minutes to one hour) using a thematically organized interview guide (Patton, 2002). Interview themes dealt with the teachers' increased roles as developers of pedagogical practices with ICT, collaboration with colleagues, educational background, competence building, and the appropriation of ICT in teaching in their schools.

In the navigating activity, we:

- Narrowed down the nexus of practice of interest: we decided to focus on teachers' participation in the infrastructuring of an educational network and more closely on their role in the digitalization of their school.
- Delineated the research question*:* we formulated our research question as "How do teachers in different schools of the educational network of a Finnish city make sense of and account for their participation in infrastructuring their educational network?".
- Analyzed the data: we explored teacher interviews to trace the main discourses circulating the nexus of practice (see above). We considered perspectives of historical body, interaction order, and discourses in place.
- Identified discourses*:* in the data, we identified three main discourses foregrounded in teachers' talk. The discourses were related to their participation in the infrastructuring of their work environment.

In the changing activity, we:

- Facilitated collaboration: we provided guidance for teachers in designing pedagogical-technological scripts for their pupils in their development project.
- Conducted interviews: we participated in reflective discussions with the teachers.
- Mediated results: we published research results and made them accessible to the teachers.

Nexus analysis drawing on the engaging, navigating, and changing research activities comes close to the research practice exploring participatory design in the wild (Karasti & Syrjänen, 2004) as teachers are considered non-professional designers in modernizing their school (e.g., as a natural part of infrastructure building). As a research strategy entailing and promoting change (Scollon & Scollon, 2004), nexus analysis approximates the philosophy of participatory design for giving a voice to actors who participate in developing ICT (Bjerknes, Ehn, & Kyng, 1987).

4 Empirical Findings

In this section, we present our findings. In analyzing the interviews with the teachers, we identified three main discourses. The first discourse concerned the teachers' investment in digitalization and having to take a stance about the curriculum reform that contained new objectives for using digital technologies in teaching. The second discourse concerned establishing the pedagogical use of ICT as infrastructuring activity. The third discourse concerned teachers' positions in their organizations and their efforts to balance discontinuities in infrastructuring related to various challenges in using shared ICT devices.

4.1 Discourse of Curriculum Alignment: Submissive and Empowered Policy Making

The curriculum reform, which contained new objectives for using digital technologies in teaching, emerged as a central thread in the teachers' accounts. This circulated sense making about issues and questions about pedagogical development with ICT with reference to the emphases in the renewed curriculum. Teachers sometimes took a submissive stance in curriculum reform (e.g., assigning agency to others) and sometimes an empowered stance (e.g., taking an active role in transforming their environments in terms of digitalization). In the interviews, the teachers were constructing their professional agency largely in terms of implementing the curriculum objectives in their teaching. Teachers described the push of the curriculum reform in various tones and, thus, revealed different motives for ICT use. In some cases, a submissive stance became prevalent, while in others, a more empowered tone became prevalent. Overall, the teachers reflected on using diverse learning technologies given that the general educational context placed demands on them with respect to digitalization. For instance, one teacher said:

> *Surely, it's more in the foreground how to bring in more digitalization and what exactly to teach them [pupils]—what they should know when they continue onwards—it is on my mind that a teacher should apply and use it more.* (I9)

The above quote also illustrates the teachers' freedom in making their choices about what and how to teach. On the other hand, teachers seemed uncertain about which particular way to go, which suggests that the local-level policies on how to put the curriculum into action remained under transformation. The same teacher voiced such concerns in saying:

> *I take it as a kind of demand so – of course it's been inscribed in that curriculum and it binds us but there's also a kind of urge from there to use it more—yes—now, in a way, a call from there, that we should use it more—like now there's this digital leap and now you must—so one should somehow be able to use it in teaching—in more versatile ways—so that's surely something that I will have to practice here*. (I9)

From these quotations, we can also see how the teacher described professional agency as something beyond teachers (e.g., "a teacher should apply it more" and "one should somehow be able to use it in teaching"). Nevertheless, the teacher wraps up the reflection in a conclusion indicating her own agency taking responsibility for action (e.g., "that's surely something that I will have to practice here").

As reasons for their reluctance to pedagogical ICT use, teachers described their accustomed practices and background as submerged in their historical bodies. They used linguistic formulations related to pedagogical experience to bring forth the tensions they faced with meeting new demands (e.g., "due to my background" (I1) and "I've become used to always working in a certain way" (I9)). The teachers even portrayed themselves as facing some form of threat as in "it's a bit like a pressure that it must be applied" (I 1) and "a little bit frightening yes…. It is some kind of specter—*undeniably"* (I9). Such accounts also foregrounded a perceived infrastructural breakdown (Pipek & Wulf, 2009) and suggested tensions between teachers' digital competences and the curriculum objectives for technology-enhanced learning.

Reconsidering pedagogical technology use in schools helped teachers develop new practices at work. The interviewees described the curriculum objectives concerning technology-enhanced learning and pupils' digital skills as having become clearer when they had become more conscious about them after the reform. The teachers also argued that clearer curriculum objectives support technology appropriation in teaching:

> *Well, in my opinion, the positive side has been in the goals involving much more awareness, so they are always based on what has been learnt in the first grade, and what comes next complements the previous layer and so on.* (I6)

The teachers constructed their agency in selecting learning technologies through accounts that highlighted their expertise in evaluation related to their historical bodies as pedagogical professionals. Such accounts foreground teachers' infrastructuring activities as they are balancing between the traditional practices and educational renewal with ICT. However, the teachers generally reasoned technology-enhanced learning to be pedagogically meaningful or enriching. Their agency became further visible in the way they described being able to align their pedagogical practices with curriculum objectives. Teachers considered pedagogical models suitable for the way in which pupils learn to provide the basis for technology appropriation:

> *When I see that it brings some joy or benefit to teaching—when I see it as a usable tool and, on the other hand, what the curriculum requirements are. Of course, the curriculum gives guidance to what needs to be learnt, what to practice.* (I7)

Besides choosing suitable pedagogical models, the teachers considered their own digital skills important in their ability to balance between different uses of technology. The recent curriculum renewal did not necessarily constitute the crucial factor that triggered every teacher's development in pedagogical ICT use. The theme has been important in the educational field since the 1990s, and many teachers have engaged in such development on a long-term basis. Thus, they have been able to follow and anticipate digitalization trends long before recent escalations in technology-enhanced learning. For this reason, these teachers have not experienced great changes to their educational practices and the requirements that the new curriculum set. Rather, they had already established pedagogical ICT use in their professional expertise as one teacher said:

> *I don't see the change because I have been using the technology from my first working year. It has always been part of my teaching. I cannot say that it would have changed in any radical way.* (I7)

As for teachers' professional agency, the curriculum reform appeared to legitimate their earlier educational choices since their historical bodies already included technology-enhanced learning. The teachers' autonomy in these cases for selecting learner-centered pedagogical models enhanced with ICT appeared to be an empowering aspect as one teacher said:

> *I have always known where the new curriculum is going, and all the time I have wanted to steer teaching towards it, but now that it has arrived, the reform, it has brought a kind of trusting feeling—that I can just freely do that work…. We don't have to take everything literally.* (I11)

The teachers' accounts on anticipating the curriculum reform created the potential for pedagogical innovation and, consequently, their role in shaping infrastructuring. An awareness of curriculum objectives paved the way for teachers' infrastructuring activities. In their accounts, the teachers constructed their agency via selecting and evaluating the technology and pedagogy they used but also via finding balance between different solutions, especially in the case of infrastructure breakdown.

4.2 Discourse of Infrastructural Continuity: Collegiality and Leadership in Establishing Pedagogical ICT Use

The second discourse concerned the teachers' concern about ensuring infrastructural continuity. Through their interview discussions, the teachers portrayed different kinds of tensions. When pondering the current situation, they reflected on their experiences and expertise (historical bodies) with respect to pedagogical ICT use as one said:

> *Really, they [technologies] have changed enormously. Like during my studies I did not even have a mobile [phone], so you can imagine what kind of an explosion there has been. And today you can use the mobile in teaching, so there has been a lot for me to learn.* (I8)

The teachers also highlighted discrepancies between those competences that their pedagogical education provided and the requirements that the curriculum set for using ICT. For example, one teacher said: "I've been through class teacher education with a specialization on technology in teacher education, so in a way there was no actual practice on ICT skills there" (I5).

Even recently graduated teachers explained having "no recollection of practicing anything" (I6) in their studies and felt they did not sufficiently understand or have the skills for guiding technology-enhanced learning.

Thus, the gap that the teachers highlighted between their digital competences and the curriculum objectives for using technology in teaching foregrounded an infrastructural breakdown (Pipek & Wulf, 2019). Traditionally, ICT teachers provide support and internal training in schools for their colleagues who have varying skills and motivations related to using technology for pedagogical purposes. We also identified such a traditional interaction order between staff in the teachers' accounts as a tendency to merely rely on the ICT teachers' expertise and support while appropriating learning technologies in teaching. For example, one teacher said:

> *I've been leaning on our ICT teachers. Somehow, I've never had a very close relationship with computers—I've been using them more when I know that there are competent skillful people in the house, then I've been drawing on their help.* (I5)

ICT teachers may even feel helpless when providing support to their colleagues as one said in noting: "You don't really know where to start—there are so many different technological possibilities" (I4). Nevertheless, the teachers emphasized their own empowered agency in developing digital competences as a component of their professional skills and a prerequisite to respond to the challenges that digitalization posed. The teachers strongly articulated the need for ICT teachers to support their empowerment in becoming technology appropriators. For example, an ICT teacher said:

> *But then there are lots of teachers that really feel helpless about it. I've seen it when visiting different classrooms to help that when all kinds of new things have popped up with terrible speed it's difficult to keep up; a teacher who doesn't have that personal interest has problems in keeping onboard. So, yes, one needs support with that.* (I4)

As for their infrastructuring activities, the ICT teacher also seemed to place importance on supporting teachers' agency and giving them space to make their own decisions in appropriating technology. Overall, the ICT teachers portrayed themselves as being placed in a central position by their profession for foregrounding local aspects of infrastructure and shaping infrastructuring (Pipek & Wulf, 2009; Star & Ruhleder, 1996).

For developing their digital competences, the teachers preferred practical and locally arranged ICT training to courses arranged separately from the pedagogical practice. Overall, the teachers voiced "low-threshold in-service training" (I10) and training "that comes here and is practical" (I9) as an expected model. Teachers appreciated creating new conventions for practical training on their schools' own devices as "[technology that] can be taken into use right away" (I4). They also perceived readily applicable pedagogical models with technologies as enhancing ICT appropriation in schools.

The curriculum reform encouraging teacher collaboration has shaped the interaction order among teachers as the traditional role ascribed to individual teachers as solitary actors (often merged in their historical bodies) has become less prevalent in education. Nevertheless, the degree to which teachers collaborated seemed to vary. In some schools, it emerged around established teacher pairs or through enabling practices and arrangements made in the school schedule. New conventions for knowledge sharing that the teachers themselves initiated have started to arise.

Teachers' accounts about developing local conventions highlighted their infrastructuring activities for ensuring infrastructural continuity. Collaborative practices whereby teachers share their experience with technology-enhanced learning with their colleagues started to take shape in the educational network. Teachers noted an open organizational culture that allowed them to freely share their experience in using ICT in the work environment as enabling their co-learning and ability to build digital competence and, thus, promoted ICT use. For example, one teacher said: "Devices are available…. Open atmosphere…. We have in fact been sharing tips and...whoever is more acquainted with these things those guide others" (I1).

The examples above illustrate the emerging conventions among teachers as collaborative resonance activities (Pipek & Wulf, 2009) that shaped infrastructuring. In terms of in-service training, these conventions foreground new kinds of interaction orders between participants as they collegially distributed knowledge in situ and not through traditional training settings separated from the ICT-use context. Furthermore, as displayed through the teachers' accounts, the interaction order between teachers and pupils started to become more multifaceted as interactional co-learning patterns became more common. For example, one teacher said: "We are learning together, both the teacher and the pupil...and pupils together, too" (I9). They mentioned the curriculum as a mediational means for making this possible.

Considering the role of school management, an open work culture was portrayed as allowing teachers to regulate their ICT appropriation activities according to their resources:

> *Then, nobody is forced here [to use ICT in teaching]. Everyone acts according to their own skills and resources—people also dare to ask here.* (I1)

Although the teachers reflected a collegial interaction order in recounting how they shared their expertise in a self-initiated manner in the workplace, school managers were expected to "enable internal ICT training", which also brought to the foreground a more traditional interaction order whereby the managers in a leadership role would guide how teachers use technologies in their teaching. Teachers envisioned

strategically managed ICT training that would provide direct paths for technology appropriation. Through such ponderings, teachers positioned themselves in a submissive role as receivers of training. For example, one teacher said:

> *We would be automatically educated because I don't know at all what I absolutely need. So, it would sort of come from the management or from the ICT teachers that it would now be good for us to concentrate on this and that. I don't always know what I have missed.* (I8)

As the teachers voiced in the interviews, the tensions between school management and teachers reflected a tension between the two kinds of interaction orders. Although the teachers may have actively created collegial practices, digitalization also seemed to direct them to expect concrete activities from the school management to support their agency in the use of ICT. For example, two teachers said:

> *In my opinion, in our school, the management has taken a very nice attitude, so that no enormous pressures are placed on anyone or anything like that. One could wish, of course, that the management would show a little more interest in ICT development—and allocate temporal resources [on ICT development] for example by reserving afternoons for training.* (I4).

> *Well, the management hasn't shown it [pedagogical vision] that much in my opinion. So, it feels like one has had to introduce pedagogics, the pedagogical viewpoint [on technology-enhanced learning]. So that could be expected from the management.* (I11)

As the examples from the teachers' accounts above suggest, school managers did not have a clear role in providing teachers with support about pedagogical ICT use. Managers' pedagogical leadership enabling technology-enhanced learning is called for.

4.3 Discourse of Organizational Balancing: Evaluation and Anticipation in Infrastructuring

The third discourse concerned the teachers' efforts to explore their position in relation to their organizational environment and practices in order to anticipate and balance discontinuities in infrastructuring related to various challenges in their schools. Using shared ICT devices emerged as one problematic topic. Teachers explained how using shared digital devices required extraneous preplanning and scheduling. For example, one said:

> *In our case, it requires at least, and everywhere else, too, organization—one needs to reserve and fetch them, so it requires preparation for the technological devices to be there to be used—for it to be natural. The fact is that we need them here, in our classroom, so they are not behind any booking system but in use all time.* (I5)

Thus, to ensure infrastructural continuity, the teachers needed to adapt their plans for technology-enhanced learning to align with their colleagues' plans. Furthermore, the teachers revealed that they selected devices based merely on availability rather than their expertise in terms of pedagogical choices. Teachers' accounts about needing to "reserve and remember" (I6) ICT devices revealed that they faced restrictions in using such devices. Consequently, teachers voiced their wishes for more seamless, pedagogy-driven use of technologies:

> *If there is such a situation that it's always possible to do things with devices, so of course the use would be more natural – that would certainly change it [the use of ICT in learning]. (I5)*

Balancing the degree to which they used shared ICT devices also foregrounded concerns about achieving the curriculum objectives. The teachers noted that they found it time consuming to use shared technologies and that such use prevented them and their students from genuinely using learning technologies. For example, one teacher said:

> *We must invest quite a lot of time on struggling with technology and we actually have devices on loan—in a way we take the device to a certain lesson and use it there, and then take the devices away and then return to the traditional school learning—so there is still a long way to genuine use of technology, I think.* (I4)

The teachers' need to balance how often they could use shared ICT devices highlights an infrastructural discontinuity. In this connection, the teachers expressed further concerns about restricted possibilities to arrange technology-enhanced learning for their pupils to practice their digital skills. For example, one teacher said: "probably not every week exactly because we don't have enough equipment" (I10).

The teachers also raised concerns about the extraneous maintenance work they had to deal with to successfully use ICT (Pipek & Wulf, 2009). They also explained shared ICT use as leading to unpredictable situations where they needed to conduct maintenance. For example, two teachers said: "iPads have not been returned in time or connected to the charger" (I5) and "checking that no inappropriate screen picture has been installed or something else that could be disturbing or irrelevant" (I6).

The teachers presented themselves as having to manage such emerging infrastructural breakdowns, which caused them to reflect on their technology-enhanced teaching practices in the classroom. The teachers' agency became visible in their ideation about future arrangements that would reduce problems and promote infrastructural continuity. For example, two teachers said:

> *So, if, for example, two classes had shared equipment, then you would use them much more because it is such a natural tool. Because it tends to be the case that the whole school uses them, the older ones and the younger ones, so there tends to be some sabotage, like when you have an unfinished thing there so another class may purposefully destroy them, as they have access to everything.* (I9)

> *Well, somehow, on a decent level, if, for example, the teacher had that iPad or two in this classroom always available, that would already take you far, because then we wouldn't need those cables or signing in and things like that.* (I11)

Another common infrastructural discontinuity that required teachers' constant guidance and maintenance work in classroom situations concerned ICT devices originally developed for personal use. The teachers highlighted constant sign-in problems with pupils' accounts on their personal laptops that they used in the classroom, which illustrates an infrastructural inconsistency that evoked teachers to reconsider their practices. They also noted signing in as one activity that students (especially the younger ones) needed to constantly practice, which limited the time they had to learn actual school subjects.

Teachers tried to envision suitable practices and technologies for daily classroom work, which highlighted their role in advancing infrastructuring's continuity. For example, one teacher said:

> *What I would wish would be—for example, a class-set of iPads, we've been talking about getting one, which would mean that you could take the iPads into your class for a month-long project, so you wouldn't have to take them away, so there could be unfinished projects there. Then you could use them flexibly during teaching and it would not be bound to the calendar.* (I7)

Overall, especially problematic infrastructural breakdowns occurred in classroom situations and required teachers' immediate maintenance work. One teacher said:

> *I'm not enough for 26 first-graders whichever subject is in question. Especially with technology, even a quarter of a class is quite a lot—then, of course, every now and then technology gives you grey hair when it doesn't function properly and starts to cause problems. Sometimes, for example, there are problems with net connectivity or whatever with some program or something else. Then the entire lesson may have been ruined because of that.* (I7)

The teachers valued the ability to simultaneously reserve assistant teachers and ICT devices on the school timetable. They also pondered their teaching practices when using ICT devices required pre-planning (e.g., dividing pupils in groups and scheduling). For example, two teachers said:

> *To some extent, the basic hindrance is not having a school assistant as a help. Really, if I start practicing with the young ones, I always have that school assistant with me in general; also, I have requested such a timetable that the assistant can be there. Then I am not feeling so unstable having to guide and help everyone all the time when there's another adult there.* (I6)

> *Sometimes I have an ICT teacher to help me, but I take care that I do not go to the IT class with the entire class. So that I have only half of the pupil group and it requires an enormous amount pre-planning.* (I8)

Furthermore, collaboration and networking helped teachers to access external resources and expertise (e.g., via participating in competitions, visiting companies, and participating in projects outside schools). For example, one teacher said:

> *Last spring, when I had the fourth grade, I took them to Fab Lab… there were laser-cutters and 3D printers, so I was like in a candy shop. And the pupils were also thrilled.* (I7)

Overall, teachers portrayed the new networking arenas as supporting their agency in using ICT and developing digital competences. The teachers (especially ICT teachers) reported that they often used the resources of a network that school administrators launched to provide new arenas for teachers to reflect and develop their professional skills. Networking widens the scale of infrastructuring and allows new configurations of interaction order between participants also beyond the school. Teachers portrayed special interest groups and platforms in social media (e.g., Internet platforms, Facebook groups) as common channels that they used to build their ICT competences since other teachers often shared their experiences in them.

Moreover, interviewed teachers from developer schools participated in workshops in which they were able to acquaint themselves with models for collaboratively evaluating the current state in schools' ICT infrastructure. Based on their participation in these workshops, they described the roadmap procedure that the workshops initiated as "useful for defining the future goals for ICT use" (I4). By working in this way, teachers also gained insight into how they could develop their schools' infrastructure. However, since this model was still in its initial phase and did not cover all city schools at the time we conducted the interviews, the teachers described the results as distant from everyday teaching. For example, one teacher said:

> *We in the development team picked those objectives based on teachers' suggestions...but not otherwise visible in our everyday practices, not to me at least (I4).*

These concrete examples that show teachers and developer teachers networking and engaging in sharing expertise in various ways highlight the teachers' role in designing their practice environment to successfully use ICT (Pipek & Wulf, 2009). In their reflections about the use of shared devices, teachers foregrounded the dynamicity of interaction among teachers and pupils. Special challenges are met when teachers need to adjust their own choices and schedules with those of the others. Such interaction requires a balanced, collegiate interaction order to function smoothly.

5 Conclusion

Although guided by curriculum objectives at the national and local levels, teachers in basic education in Finland can autonomously choose their educational approaches and solutions and engage in transforming their school environment in various ways. Accordingly, in this study, we interviewed 12 teachers who constituted influential actors in infrastructuring a Finnish city's educational network. They played a role in ensuring continuity in infrastructuring with an overall aim to digitalize their schools. Teachers contributed to infrastructuring by adapting pedagogical practices with ICT to the local settings of their schools.

The ethnographic stance of nexus analysis involved researchers recurrently asking what was occurring in the field in terms of the social action in focus. In analyzing teachers' accumulated experiences through the historical body concept, we identified infrastructuring's historical and anticipatory aspects. In addition, we relied on the interaction order concept to examine the social actors' social arrangements as influential in infrastructuring. Furthermore, we examined the circulating discourses in place. As a result, we identified three main discourses teachers' participation in infrastructuring (see Figure 1).

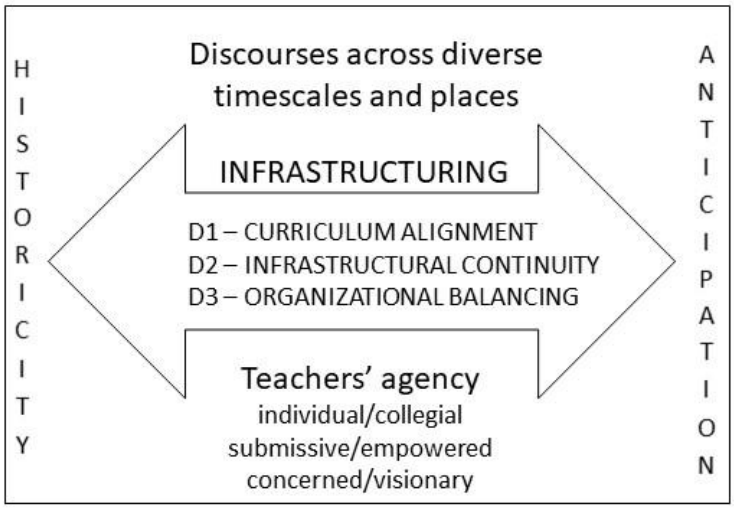

Figure 1. Discourses Circulating Infrastructuring the Educational Network according to the Teachers

The first discourse concerned the curriculum reform that assigned teachers new objectives for using digital technologies in teaching. Teachers contemplated their experiences, understandings, and practices (historical bodies) and, thus, engaged in identity work as pedagogical professionals. They recounted how they evaluated the pedagogical benefits in using ICT for both learners' and their own digital skills and digital competencies. To balance the traditional and new educational solutions, teachers aligned their pedagogy-driven practices with the curriculum objectives and by drawing on their historical bodies. These situated design activities focused on ensuring continuity in infrastructuring (Pipek & Wulf, 2009; Star & Ruhleder, 1996). The teachers were concerned about the tensions between infrastructuring's local and global aspects (Star & Ruhleder, 1996) that changes in the educational environment and their schools' organizational conventions caused. On the other hand, the teachers reflected on how the new curriculum had legitimized at the policy level what they had anticipated and envisioned about pedagogical ICT use. This discourse represents an important contribution to infrastructuring research. It highlights that teachers' situated design practices as infrastructuring activities (Pipek & Wulf, 2009; Ludwig et al., 2018) do indeed arise from their reconsidering the way they currently use infrastructure and recognizing potential educational innovations (Pipek & Wulf, 2009). However, we found that teachers varied in how much agency they perceived themselves to have in advancing innovations: they sometimes depicted themselves as submissive and sometimes as empowered actors. This finding suggests differences in the interaction orders at work in the schools that entailed different relational power structures between staff members.

The second discourse concerned infrastructuring activities that teachers used to successfully establish pedagogical ICT use (Pipek & Wulf, 2009). Teachers emphasized continuous professional development for constructing digital competences to enable their empowered agency with ICT. Building ICT competence emerged in the data as one of the teachers' essential infrastructuring activities (Pipek & Wulf, 2009). We identified how teachers embraced both a troubled and an empowered stance to the pedagogical ICT use. To renew educational practices, teachers performed situated infrastructuring design activities (Pipek & Wulf, 2009) such as evaluating, selecting, and balancing pedagogy-driven ICT use based on their individual experience (historical body). On the other hand, to ensure infrastructural continuity, teachers seemed to rely on distributed expertise (interaction order drawing on collegiality). For being able to successfully establish the use of ICT, teachers were initiating new collegial practices for sharing expertise on the pedagogic use of ICT, which are characterized as resonance activities in infrastructuring (Pipek & Wulf, 2009; Ludwig et al., 2018). Considering the interaction order, the teachers' discourses highlighted their reliance on local ICT support and training in using resources in situ. The traditional interaction order among school actors seemed to persist in the teachers' expectations for strategically managed leadership in organizing in-service education and providing enabling practices to support ICT use.

The third main discourse highlighted discontinuities and anticipations in infrastructuring (Star & Ruhleder, 1996) through foregrounding challenges in sharing ICT devices. To ensure situated resources, teachers

made their ICT choices due to availability rather than pedagogical goals, which reflects an infrastructural breakdown (Star & Ruhleder, 1996). Thus, teachers had to balance their individual educational practices with the social practices and organizational infrastructures in their school. Teachers needed to align their individual pedagogical approaches with their school's institutional culture emerging from the inter-relationships among staff (interaction order). Furthermore, the teachers expressed the challenges of having to deal with ICT maintenance work on a regular basis (i.e., to ensure infrastructural continuity)(Star & Ruhleder, 1996). Moreover, the teachers' collegiality in developing new conventions to cope with limited organizational ICT resources required their anticipations in infrastructuring. Thus, in line with the literature, the teachers balanced controversial infrastructure activities (Björgvinsson et al., 2010, 2012a).

As part of their collaborative resonance activities, teachers collaborated and shared knowledge, which they felt was empowering their design activities (e.g., Pipek & Wulf, 2019; Ludwig et al., 2018). Our findings that teachers relied on distributed expertise and collegiality emphasizes collaboration's role as an influential aspect in infrastructuring (e.g., Pipek et al., 2017.). These findings are in line with infrastructuring and collaborative design research in the participatory CSCW field (Pipek et al., 2017; Karasti et al., 2018). In a similar vein, collaboration is a central concern in research on infrastructuring as social innovation (Björgvinsson et al., 2010). Similarly, the teachers identified enabling practices that headmasters arranged along with the open school culture as supporting their experimenting with ICT. The teachers valued global networks as resources for professional development in terms of digital skills even if they preferred the support they received from their local networks.

Our study has several implications for research and practice. Methodologically, with this paper, we contribute to earlier research on participatory infrastructuring. Our decision to use nexus analysis to examine infrastructuring comes close to participatory design "in the wild" (e.g., as a natural part of infrastructure building) (see Karasti & Syrjänen, 2004). Teachers' local infrastructuring activities (e.g., Pipek & Wulf, 2009) included building digital competences, maintaining infrastructuring's continuity, and balancing (sometimes controversial) organizational infrastructures (e.g., Björgvinsson et al., 2010, 2012a). These implications of the study related to users' infrastructuring activities contribute to the current calls on participatory infrastructuring practices in order to expand the scope of related design activities and participants (e.g., Bødker et al., 2017). In using nexus analytical concepts, we provide valuable insight into power-related aspects, related to the participation of practitioners and their contribution to infrastructuring. Furthermore, by using historical body as a tool, we sensitized our analysis to the local practices and infrastructure base to which the new elements had to adapt (Star & Ruhleder, 1996). Motivational, historical, and power-related understandings promote practitioners' activities for infrastructuring. Moreover, recognizing historical aspects may facilitate emerging local social needs in infrastructuring and help actors balance the local-global scales (Karasti, 2014). Conceiving social action as an intersection between historical body, interaction order, and discourses in place allows researchers to closely examine sociocultural histories and social arrangements that contribute to infrastructuring (Scollon & Scollon, 2004). Through "infrastructural inversion" (Bowker, 1994), these nexus analysis tools foreground infrastructuring's transparent, background, and historical elements (Star & Ruhleder, 1996). Rather than treating the notion of infrastructuring as connected with professionalized design, existing literature sees infrastructuring as including various people as "users" and "designers" (Björgvinsson et al., 2010, 2012; Karasti, 2014; Karasti & Baker, 2004; Karasti & Syrjänen, 2004; Pipek & Wulf, 2009). Therefore, with this study, we contribute to IS research by offering nexus analytic tools to explore the often unseen infrastructural activities of practitioners who participate in infrastructuring.

Practically speaking, our findings suggest that schools and educational networks that develop leadership and collegial support may provide a fruitful platform for teachers' in-service training locally in the workplace and enhance their empowerment to meet challenges in situ. Digitalizing schools requires opportunities for teachers to strengthen their agency and digital competences as part of their continuous professional development as an important activity in infrastructuring.

Our study has several limitations. We could have used a broader range of research materials (video recordings and observations from in-situ encounters in the study context) to understand the phenomenon we studied more thoroughly. Researchers need to more closely examine social action's dimensions and related discourses to better understand the dynamics and intricate arrangements between actors. However, by analyzing interviews from a discourse perspective, we better understand the role that teachers as actors and their interactions played in infrastructuring the educational network. As we collected diverse research material through a collaborative research intervention with teachers, plentiful possibilities for further research remain.

Acknowledgments

We thank the teachers and schools involved in the development project and the interviews. The Jenny and Antti Wihuri foundation funded this work.

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