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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, there is great diversity between schools in terms of their degree of digitalization. New curricula in Finland are putting additional pressure on education to meet the goals of the 21st century. In information systems (IS) research, digitalization increases an interest for understanding modern IS projects as infrastructuring. This study examines the infrastructuring of the educational network of a Finnish city from the perspective of teachers as influential actors in transforming their environment. A nexus analysis of interviews foregrounded three main discourses circulating the teachers' participation in infrastructuring. 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, and the third discourse highlighted practices of sharing resources as an effort of organizational balancing. The results reveal tensions between collegiality and leadership, submissive and empowered agency, and discontinuities and anticipation in ensuring continuity in infrastructuring. The study provides 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
1 Introduction

The rapid evolution of digital technologies has changed the ways in which people interact with and through technologies. In the study of Information Systems (IS), digitalization has raised an interest in 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, involving not only professional designers, but varied kinds of “users” and “designers” (Star & Bowker, 2006; Pipek & Wulf, 2009; Björgvinsson, Ehn & Hillgren, 2010, 2012a; Karasti & Baker, 2008). Infrastructuring refers to an activity that is natural for all practitioners as designers of their own practice environment to successfully establish the use of information technology (Pipek & Wulf, 2009).

This study approaches infrastructuring in the field of education, where teachers are in a central position 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 taken place in the practices of teaching and learning on a wide scale (Yelland, 2018). In some schools, the solutions promoting digitalization and 21st-century skills have merged into their daily life, while in others, major discontinuities are experienced in relation to the use of technology. Technology has often remained as an add-on rather than a natural resource for learning. Finnish schools have been said 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 COVID19 epidemic suddenly closed all schools in Finland and teachers had to move online in spring 2020. This raised stories of innovative solutions, but also parents’ complaints about the mechanical exchange of tasks and answers, and teachers’ despair about how to handle teaching when their pupils are not physically in class. The situation triggered an active development of pedagogical practices for technology-mediated interaction and learning, which will potentially have its impact on life in schools even after the COVID19 lockdown. The key actors in contributing to change are teachers as they have great freedom in Finland in how educational policies, strategies and national curricula are put into action on a local level.

This study explores how teachers in different schools of a city in Finland make sense and account for their participation in infrastructuring their educational network. In previous research, the complexity and participation of a multitude of actors involved in infrastructuring have been studied in the educational network of a Finnish city (Halkola & Iivari, 2014; Halkola, Iivari & Kuure, 2015). This research complements these studies with in-depth analysis focusing on teachers’ infrastructuring activities. The research strategy of this study is nexus analysis (Scollon & Scollon, 2004), because this allows the study of discourses emerging in social action, at the same time linked with more distant discourses with societal relevance. Twelve teachers who had been taking part in collaborative planning and experimenting with technology-enhanced learning in their schools in Finland were interviewed to gain their perspectives as key social actors in the potential digitalization of their school, the nexus of practice of interest in this study. In the interviews, the teachers were pondering the role of technology in their daily pedagogical practices, how they cope with the integration of pedagogy and technology, what kinds of breakdowns emerge, and how they are solved, and what the teachers’ degree of agency is in this matter. The interviews themselves contribute to potential change, a central aim of nexus analysis, as the teachers are becoming aware of their role in infrastructuring related to the digitalization of their school.

In the following section, a theoretical grounding is provided for the research on digital technology in basic education in Finland, digital competence and digital literacies. Following this, the definitions are presented for the notions of information infrastructure (II) and infrastructuring which is continued with the delineation of the research method and the procedures for data gathering and analysis. The final sections present empirical results, while the concluding discussion identifies implications and limitations of the results outlining paths for future work.

2 Related research

The following sections provide background information on the educational reform related to digital technology in basic education, digital competence and digital literacies. In addition, related research for defining the notions of II and infrastructuring is presented.
2.1 Information Infrastructure and Infrastructuring

Star and colleagues (Star & Ruhleder, 1996; Star, 1999; Bowker & Star, 1999) provide their well-known relational and socio-technical characterization of II: it evolves through the intertwining of the locally tailored technologies and the elements of formal infrastructure. Relational to the local practices of a community, the emergence of a transparent, supportive infrastructure transforms in response to community evolution and adoption. II’s need to be changeable to support prevalent organizational conventions as well as the evolving practices and the use of technology. When larger-scale technology influences local practices, the alignment of the local and global elements of infrastructure may cause tensions. These tensions need to be resolved to allow the use of the infrastructure in a natural, ready-to-hand fashion (Star & Ruhleder, 1996).

Numerous independent actors, developers, and users are involved in the evolving, large-scale and complex socio-technical entanglements of II’s (Hanseth, 2010). In the context of Participatory Design (PD), for example, stakeholders’ perspectives have drawn attention due to political and ethical concerns relevant in design (Star & Bowker, 2006; Neumann & Star, 1996; Karasti, 2014). The role of non-professional designers has also been important in relation to communities in PD emerging ‘in-the-wild’ (Karasti & Syrjänen, 2004). Additionally, there has been a call for a more detailed examination of political aspects in the field of PD in infrastructuring due to the increasing versatility of the conditions for user participation (Karasti, 2014).

A growing body of research on the formation and design of infrastructures 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 also consider infrastructuring a central issue for modern innovation, which demands extensive collaboration among many stakeholders over time (Björgvinsson et al., 2012b) and sustaining relationships for design opportunities to emerge (Hillgren, Seravalli & Emilson, 2011). Participation has evoked discussions on the need for open-ended professional design of potential public matters that through infrastructuring can become objects of design-in-use to the participants and how they may appropriate them (Ehn, 2008).

The concept of infrastructuring refers to the tentative, flexible, and open process of building and the evolution of II’s described above (Star & Bowker, 2006). The borders between use and design become blurred due to ongoing changes, ease of maintenance and long-term tailoring of flexible and adaptable systems (Karasti & Baker, 2004; Karasti & Syrjänen, 2004). Hence, the users’ role in infrastructuring has been widely researched. 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 the design and implementation of infrastructures is primarily based on users’ actual use of technology. Users’ activities in infrastructuring are understood as reconceptualizing one’s own work in the context of existing, potential, or envisioned ICT tools that are natural parts of users’ activities. Practitioners have an important role as designers of their own practice environment to successfully establish the use of ITC. The in-situ design activities that the users are performing may relate to configuring, tailoring or developing new conventions until the use of technology is successfully established. End-user-driven infrastructuring activities also include ‘resonance activities’ which 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 users’ recognition of potential innovations, and reconsideration of current infrastructural use. Thus, various motivational forces may evoke a reconsideration of practice – they entail a dependency on the invisibly supporting infrastructure, usually related to actual or perceived infrastructure breakdown, and extrinsically or intrinsically motivated practice innovation (Pipek & Wulf, 2009; Ludwig, Pipek & Tolmie, 2018).

Studies in the field of Participatory CSCW (computer-supported cooperative work) further direct interest in infrastructuring and collaborative design (Pipek, Karasti & Bowker, 2017; Karasti et al., 2018), approaching infrastructuring as part of the design and use of information technologies (Pipek & Wulf, 2009, p. 447.) The recent special issues of the CSCW journal particularly bring to focus the processual (in-the-making) perspective and/or design-oriented engagement with II’s (Pipek et al., 2017; Karasti et al., 2018).

Infrastructuring is seen to extend the temporal, organizational and societal scopes as well as 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, as well as community members and citizens in informal, community-based initiatives (Pipek et al., 2017).
Furthermore, recent research on infrastructuring addresses invisibility, relationality and connectedness as the most salient dimensions of infrastructuring for analysis (Simonsen, Karasti & Hertzum, 2020; Karasti & Blomberg, 2018). The very recent literature 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 notion of II, combined with the concept of infrastructuring that brings along a process ontology (Karasti et al., 2018).

The concept of infrastructural inversion (Bowker, 1994) has been used to capture the transparent, background and historical elements of infrastructure (Star & Ruhleder, 1996; Star, 2002). This entails IIs being built on an installed base (Star & Ruhleder, 1996; Hanseth, 2010) and becoming visible upon breakdown (Star & Ruhleder, 1996, pp. 5–6). In recent literature, the concept refers to the tracing and foregrounding of concrete infrastructural relations and connectedness (Simonsen, Karasti & Hertzum, 2020).

2.2 Teachers and the Digitalization of Schools in Finnish Basic Education

The digitalization of society in the last few decades has raised concerns in education that have been studied widely. However, there is lacking consensus about its specific educational effects (Pettersson, 2018, p. 1015). Despite the longstanding investment in equipping schools with ICT, teacher education, and the training of teachers in service, there is great diversity in learning environments and experiences that education can offer, and approaches to learning that are promoted (Tanhua-Piironen et al., 2016; Vahtivuori-Hänninen & Kynäsälähti, 2016; Chaudron, Di Gioia & Gemo, 2018, pp. 82–84; Mulari & Vilmilä, 2016; European Union, 2019). Society expects changes in education with teachers becoming change-agents in the transformation of learning approaches drawing on a variety of resources including ICT (European Union, 2019; Redecker, 2017).

In UNESCO’s (2011) framework for digital competency, teachers are expected to create educational activities that help students become collaborative, problem-solving, creative learners with the help of ICT. This will lay the foundation for the students’ growth towards effective citizenship and competence as members of the workforce. Digital competence has also been outlined among the key competences for lifelong learning in European recommendations (Council for the European Union, 2018). According to the recommendations, it involves confidence and a critical stance in using the technologies of information society for work, leisure and communication. As Ilomäki, Kantosalo and Lakkala (2011) suggest, this entails the mobilization of knowledge, cognitive and practical skills, as well as social and behavioral components, including attitudes, emotions, values, and motivations. Digital competence is also a highly political term reflecting beliefs and wishes about those skills necessary in future for capable citizens (Ilomäki, Paavola, Lakkala & Kantosalo, 2016).

Jewitt (2008, p. 255) suggests that it is increasingly important for schools to attend to students’ diverse ways of meaning making and literacy practices, especially acknowledging their multilingual, multimodal and digital aspects – not as isolated sets of skills and competences but as an intertextual web of contexts and media. This poses a challenge in pedagogical development, because the pervasiveness of media and technologies has not necessarily led to renewed practices in the educational context, for example, in the case of literacy teaching (see also Sefton-Green, Nixon & Erstad, 2009; Yelland, 2018, p. 849). Ilomäki, Paavola, Lakkala and Kantosalo (2016, p. 671) propose that digital technologies should be included in a ubiquitous way in all learning and teaching. It should not be treated as a specific “content” to be learnt but a pedagogical approach across various school subjects. This is in fact seen in Finnish curricula where the development of digital skills is one of the transversal competences that should be integrated in all school subjects (FNBE, 2014).

In Finland, national curricula give guidelines for different fields of education, and which education providers put into action through local-level and school-specific curricula. The national curriculum for basic education, renewed in 2014, puts emphasis on the integration and dialogue between different school subjects (FNBE, 2014). Seven areas for transversal competence are described, each involving growing knowledge, skills, values, attitudes and will, with a linkage to subject-specific objectives. These areas include: 1) thinking and learning to learn; 2) cultural competence; interaction and expression; 3) taking care of oneself, managing daily life; 4) multiliteracy; 5) ICT competence; 6) working life competence and entrepreneurship, as well as 7) participation involvement and building a sustainable future (FNBE, 2014). As for ICT, teachers are encouraged to advance digitalization comprehensively in their teaching (FNBE, 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 the ongoing digitalization of basic education, teachers are expected to become ICT-competent developers of their work practices and work environment, and collaborate more with their colleagues (Vangrieken, Dochy, Raes & Kyndt, 2015). In the infrastructuring process of the educational network, teachers thus have a central role as appropriators of technology in the everyday settings and practices in their schools.

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

Various national measures have been taken to support teachers in contributing to the digitalization of schools. For example, a peer-group mentoring program has been launched to enhance dialogue and knowledge sharing between teachers in a non-hierarchical way (European Union, 2019; Geeraerts et al., 2015). Active hands-on workshops, MOOCs (Massive Online Open Courses) and webinars are available. Teachers also share ideas and experiences in their own web-based networks (European Union, 2019). This kind of investment in in-service teacher education is necessary because challenges still prevail in promoting 21st-century skills and transforming schools into learning environments for the future.

3 Research Method

In this study, the broad framework of nexus analysis (Scollon & Scollon, 2004) serves as a research strategy because it allows the extension of the research perspective from a micro level to the organizational and institutional levels of social analysis. Nexus analysis is based on a mediated view of social action involving three aspects simultaneously and intertwiningly in situ. The first of these is interaction order, that is, mutual relationships and social arrangements between social actors (Scollon & Scollon, 2004, applying Goffman, 1983). The second is historical body, or participants’ personal histories, social identities and roles with the action (Scollon & Scollon, 2004, applying Nishida, 1958). The third is discourses in place, which refers to the semiotic systems emerging in situ, echoing the past and anticipating the future (Scollon & Scollon, 2004, 2003, p. 17). Discourses may cycle at a rapid pace, as in conversational encounters, or more slowly, as evolving topics in the media. Thus, discourses may be related 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 level).

The focal point of the analysis is a nexus of practice, a linkage of recognizable, multiple practices that the researchers also need to enter to find their zone of identification (Scollon & Scollon, 2004, p. 156). In the context of this study, the nexus of practice of interest is teachers’ participation in the infrastructuring of an educational network, and, more closely, their role in the digitalization of their school. As for the researchers’ zone of identification with this nexus of practice, the first author was involved in planning and conducting participatory research activities in the schools including the interviews. Previous research experience on children’s participation in the infrastructuring of an educational network led the author to focus on the teachers’ role in this area as well. The second author has studied the same field, but from the perspective of the humanities, 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, p. 9–10). These activities rather express the depth and scale of the study than consecutive phases. Engaging the nexus of practice is the opening task, the researchers establishing the social issue to study, reflecting on their zone of identification with the topic, and tracing the crucial social actions and participants. When navigating the nexus of practice, the researchers acquire and generate data, examine the most important discourses zooming in and out the nexus of practice through the materials (Larsen & Raudaskoski, 2019; Nicolini, 2010). Changing refers to the researchers seeking to transform the nexus of practice, which can be seen either as a stance of social activism or the impact of any research
raising the awareness of those researched about the issues at hand. These activities can be repeated, or they can intertwine in many ways in the course of research (Scollon and Scollon, 2004, p. 9–10).

The research advanced as follows, through three activities of nexus analysis. Considering the division of labor between the authors, the first author participated in all the activities outlined below, while the second author participated in analyzing the data and interpreting the results.

Engaging the nexus of practice

- **Identifying key actors:** Teachers with an influential role in infrastructuring their educational network, that is, developing pedagogical practices related to the digitalization of their schools.
- **Establishing shared ground:** Contacts with local educational officials; participating in meetings with headmasters of schools in the educational network to introduce planned research activities; discussing detailed plans of the study through email and in a meeting.
- **Inviting participants:** Twelve teachers to be interviewed from a developer-school network in the city (basic education, grades 1–6).
- **Generating research data:** Conducting interviews (30 min – 1 h) 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.

Navigating the nexus of practice

- **Narrowing down the nexus of practice of interest:** Teachers’ participation in the infrastructuring of an educational network, and more closely their role in the digitalization of their school.
- **Delineating the research question:** 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?
- **Data analysis:** Exploring teacher interviews to trace the main discourses circulating the nexus of practice (see above). Perspectives of historical body, interaction order and discourses in place considered.
- **Identifying discourses:** Three main discourses foregrounded in teachers’ talk, circulating their participation in the infrastructuring of their work environment.

Changing the nexus of practice

- **Facilitating collaboration:** Providing guidance for teachers in designing pedagogical-technological scripts for their pupils in their development project.
- **Conducting interviews:** Participating in reflective discussions with the teachers.
- **Mediating results:** Publishing research results and making them accessible by the teachers.

Nexus analysis drawing on the research activities of engaging, navigating and changing the nexus of practice of interest comes close to the setting of participatory design (PD) ‘in-the-wild’ setting (Karasti & Syrjänen, 2004) in relation to modernizing the 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 involved in ICT development, allowing them to “have a say” (Bjerknes, Ehn & Kyng, 1987).

### 4 Empirical Findings

In the following, the findings of the study are presented. The analysis of the interviews with teachers brought to the foreground three main discourses. The first was related to the teachers’ investment in digitalization, having to take a stance to the curriculum reform which assigns new objectives for utilizing digital technologies in teaching. The second discourse concerned establishing the pedagogical use of ICT as infrastructuring activity, while the third main discourse highlighted the teachers’ positions in their organizations trying to balance with discontinuities in infrastructuring related to various challenges in the use of shared ICT devices.
4.1 Discourse of Curriculum Alignment - Submissive and Empowered Policy Making

The curriculum reform, which assigns new objectives for the use of digital technologies in teaching, was a central thread in the teachers’ accounts. This discourse of curriculum alignment circulated sense making about issues and questions of pedagogic development with ICT with reference to the emphases in the renewed curriculum. Sometimes, teachers were taking a submissive stance assigning agency to others, and sometimes an empowered stance, 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. The push of the curriculum reform was constructed in various tones, revealing different motives for the use of ICT. In some cases, a submissive stance to change was in the foreground, and in others, a more empowered tone became prevalent. Overall, the teachers reflected on a diversified use of learning technologies from the perspective of the general scene in education placing demands on teaching with respect to digitalization:

1. Surely, it’s more in the foreground how to bring in more digitalization and what exactly to teach them – what they should know [related to technology and learning] when they continue onwards – it is on my mind that a teacher should apply and use it more (I 9).

Example 1 further illustrates the teachers’ freedom in making their choices about emphases in teaching outlined broadly in the national curriculum. On the other hand, teachers seem to be uncertain about which particular way to go, which suggests that the local-level policies on how to put the curriculum into action are still under transformation. Similar concerns are voiced here in Example 2:

2. 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 (I 9).

Teacher professional agency is visible in the examples as something beyond the speaker: a teacher should apply it more (Example 1), one should somehow be able to use it in teaching (Example 2). Nevertheless, the teacher wraps up the reflection in a conclusion indicating personal agency (that’s surely something that I will have to practice here).

As reasons for their reluctance to the pedagogical use of ICT, teachers described their accustomed practices and background, submerged in their historical bodies. Linguistic formulations related to pedagogical experience were used to bring forth tensions facing new demands: due to my background (I 1); I’ve become used to always working in a certain way (I 9). 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 (I 9). Such accounts also foregrounded a perceived infrastructural breakdown (Pipek and Wulf, 2009) suggesting tensions between teachers’ digital competences and the curriculum objectives for technology-enhanced learning.

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

3. 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 (I 6).

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, balancing between the traditional practices and educational renewal with ICT. However, teachers generally reasoned technology-enhanced learning to be pedagogically meaningful or enriching learning. Their agency became further visible in their descriptions of being able to align their pedagogical practices with curriculum objectives. Teachers considered pedagogical models suitable for pupils’ ways of learning to provide the basis for technology appropriation:
4. 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 (I 7).

Besides choosing suitable pedagogical models, the teachers considered their own digital skills important in balancing with the use of technology. The recent curriculum renewal was not necessarily the crucial factor triggering development in the pedagogical use of ICT in the case of all teachers. The theme has been important in the educational field since the 1990s, and many teachers have engaged in development on a long-term basis. Thus, they have been able to follow and anticipate trends of digitalization long before the current escalation of technology-enhanced learning. For this reason, these teachers have not experienced great changes to their educational practices and the requirements set by the new curriculum. Rather, the pedagogical use of ICT has already become submerged in their professional expertise:

5. 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 (I 7).

As regards teachers’ professional agency, the curriculum reform appeared to legitimate their earlier educational choices, as technology-enhanced teaching had already become submerged in their historical bodies. The teacher’s autonomy in these cases for selecting learner-centered pedagogical models enhanced with ICT appeared to be an empowering aspect:

6. 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 (I 11).

The teachers’ accounts on anticipating the curriculum reform bring forth the potentials for pedagogical innovation and, consequently, the teachers’ roles in shaping infrastructuring. An awareness of curriculum objectives paved the way for teachers’ infrastructuring activities. In their accounts, the teachers constructed their agency in terms of selecting and evaluating the use of technology and pedagogy, but also balancing, especially in the case of infrastructure breakdown.

4.2 Discourse of Infrastructural Continuity – Collegiality and Leadership in Establishing Pedagogical use of ICT

The second discourse circulated around the teachers’ concern about ensuring infrastructural continuity. Through their interview discussions, the teachers portrayed tensions of different kinds. When pondering the current situation, they reflected on their experiences and expertise considering the pedagogical use of ICT, which is their historical bodies as professionals with respect to their digital competences:

7. 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 (I 8).

Teachers also highlighted discrepancies between those competences provided by their pedagogical education and the requirements set by the curriculum for the use of ICT.

8. 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 (I 5).

Even recently graduated teachers explained having no recollection of practicing anything (I 6) in their studies, feeling they were lacking understanding and skills for guiding technology-enhanced learning.

The gap that the teachers were highlighting between their digital competences and the curriculum objectives for the use of technology in teaching, thus, foregrounded an infrastructural breakdown (Pipek & Wulf, 2019). Traditionally, ICT teachers are assigned to providing support and internal training in schools for their teacher colleagues who have varying skills and motivations related to learning the use of technology for pedagogical purposes. Such a traditional interaction order between staff was also visible in the teachers’ accounts as a tendency to merely rely on the ICT teacher’s expertise and support while appropriating learning technologies in teaching:
9. 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 (I 5). ICT teachers may even feel helpless when providing support to their colleagues as you don’t really know where to start – there are so many different technological possibilities (I 4). Nevertheless, teachers emphasized their own empowered agency in developing digital competences as a component of their professional skills, as a prerequisite for responding to the current challenges of digitalization. The need for supporting teachers’ empowerment in becoming technology appropriators was strongly articulated:

10. 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 (I 4).

Considering teachers’ infrastructuring activities, enabling teachers’ agency by giving space for their own decisions in technology appropriation seemed to be important for the interviewees. Overall, the ICT-teachers portrayed themselves to be in a central position by their profession for foregrounding the local aspects, 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 pedagogic practice. Overall, the teachers voiced low-threshold in-service training (I 10) as an expected model, training that comes here and is practical (I 9). Teachers appreciated creating new conventions for practical training on schools’ own devices as [technology] can be taken into use right away (I 4). Readily applicable pedagogical models with technologies were also seen as enhancing ICT appropriation in schools.

The curriculum reform encouraging teacher collaboration is shaping the interaction order among teachers as the traditional role ascribed in the historical body of an individual teacher as a solitary actor is becoming less prevalent in education. Nevertheless, the degree of collaboration among teachers seems 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 initiated by teachers themselves have started to arise.

Teachers’ accounts on developing local conventions highlighted their infrastructuring activities for ensuring infrastructural continuity. Collaborative practices whereby teachers share their experiences of technology-enhanced learning with their colleagues have started to take shape in the educational network. Open organizational culture, allowing free sharing of experiences on the use of ICT in the work environment was expressed as enabling teachers’ co-learning and building of digital competence, thus promoting the use of ICT: devices are available [...] open atmosphere [...] we have in fact been sharing tips and [...] whoever is more acquainted with these things those guide others (I 1).

The examples above illustrate the emerging conventions among teachers as collaborative resonance activities (Pipek & Wulf, 2009) shaping infrastructuring. In terms of in-service training, these conventions foreground new kinds of interaction orders between participants as knowledge is distributed collegially in situ and not through traditional training settings separated from the context of the use of ICT. Furthermore, as displayed through the teachers’ accounts, the interaction order between teachers and pupils has started to become more multifaceted as interactional patterns of co-learning are becoming more common: we are learning together, both the teacher and the pupil [...] and pupils together, too (I 9). The curriculum was mentioned 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:

11. 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 (I 1).

Although a collegial interaction order was reflected in the teachers’ accounts of everyday self-initiated sharing of expertise in the workplace, the expectations of the school management to “enable internal ICT training” also brought to the foreground a more traditional interaction order with the management being in a leadership role, guiding the pedagogic use of technologies. In teachers’ accounts, calls for strategically managed ICT training providing direct paths for technology appropriation were brought forth, positioning teachers rather in the submissive role as receivers of training:
12. 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 (I 8).

The tensions between school management and teachers, as voiced in the interviews, reflected a balancing between two kinds of interaction orders. Although the teachers may be active in creating collegial practices, digitalization also seems to direct them to expect concrete activities from the school management to support their agency in the use of ICT:

13. 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 (I 4).

14. 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 (I 11).

As the examples from the teachers’ accounts above suggest, the role of school management in providing support in the pedagogic use of ICT is not clear-cut. While teachers are striving with the local arrangements and the shared ICT equipment in their schools, pedagogical leadership assigned with technology-enhanced learning is called for.

4.3 Discourse of Organizational Balancing - Evaluation and Anticipation in Infrastructuring

Through the third discourse, the teachers explored their position in relation to their organizational environment and practices, trying to anticipate and balance with discontinuities in infrastructuring related to various challenges in their schools. One problematic topic was the use of shared ICT devices. Teachers explained how the use of the shared digital devices required extraneous preplanning and scheduling:

15. 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 (I 5).

Thus, for ensuring infrastructural continuity, teachers needed to adapt their plans for technology-enhanced learning to align with their colleagues’ plans. Furthermore, teachers’ accounts revealed that selecting devices was merely based on availability rather than teachers’ expertise in terms of pedagogical choices. Teachers’ accounts of needing to reserve and remember (I 6) the ICT devices revealed a restriction for their use contrary to the ideal of being seamless in pedagogical use. Consequently, the anticipations for more apparent use of technologies were voiced:

16. 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] (I 5).

Balancing with the use of the shared ICT devices also foregrounded concerns about achieving the curriculum objectives. Teachers explained the use of shared technologies not only as time-consuming but even as disabling the genuine use of learning technologies:

17. 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 (I 4).

Needing to balance with a limited amount of 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, probably not every week exactly because we don’t have enough equipment (I 10).
Teachers' discourse revealing concerns was also related to the extraneous maintenance work they had to deal with to successfully establish the use of ICT (Pipek & Wulf, 2009). Shared use of ICT devices was also explained as leading to unpredictable situations where maintenance was needed: *iPads have not been returned in time or connected to the charger* (I 5); *checking that no inappropriate screen picture has been installed or something else that could be disturbing or irrelevant* (I 6).

Teachers presented themselves as having to manage such emerging infrastructural breakdowns, which evoked a reflection on their technology-enhanced teaching practices in the classroom. Teachers’ agency became visible in their ideation for future arrangements which would reduce problems and promote infrastructural continuity:

18. 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 (I 9).

19. 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 (I 11).

Another common infrastructural discontinuity requiring constant teachers’ guidance and maintenance work in classroom situations was related to the use of ICT devices originally developed for personal use. Constant sign-in problems with pupils’ accounts on laptops in shared use were highlighted by the teachers, which is an example of infrastructural inconsistencies evoking teachers to reconsider their practices. Signing in was also addressed as one of the activities requiring constant practicing, especially with younger pupils, limiting the learning time for the actual school subject.

In pondering on their practices of the use of technology, teachers were trying to envision suitable practices and technologies for daily classroom work. This highlights the teachers’ role in advancing the continuity of infrastructuring:

20. 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 (I 7).

Overall, especially problematic infrastructural breakdowns were those occurring in classroom situations, requiring teachers’ immediate maintenance work during the lessons:

21. 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 (I 7).

The teachers valued the emergence of the practice of reserving assistant teachers simultaneously with the reservation of ICT devices from the school timetable. They also pondered on their teaching practices when using ICT devices required pre-planning (e.g., dividing pupils in groups and scheduling):

22. 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 (I 6).

23. 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 (I 8).

Furthermore, collaboration and networking brought external resources to teachers’ use. Overall, the new networking arenas were portrayed as supporting teachers’ agency in the use of ICT and the development
of digital competences. By profession, especially ICT teachers are often participating in developer teachers’ network, launched by the school administration as a resource providing new arenas for reflection and professional development. Widening the scale of infrastructuring through networking also highlights new kinds of interaction orders among the actors of schools. Special interest groups and platforms in social media (e.g., Internet platforms, Facebook groups) were portrayed as common channels for teachers to build their ICT competences, as if you need something, you can find shared experiences there [Facebook group on iPads] (I 10). Furthermore, participation in competitions, visits to companies and projects outside the school are examples of the available extended digital resources and expertise:

24. 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 (I 7).

Moreover, each selected developer school in focus was participating in workshops providing models for collaboratively evaluating the current state in school’s ICT infrastructure. Based on their participation in such a participatory workshop, they described the roadmap procedure initiated there as useful for defining the future goals for ICT-use (I 4). By working in this way, teachers’ insights into the development of their school infrastructure were also gained. However, as this model was in its initial phase and only later included in the development plan for all city schools, the results were ascribed as still distant from everyday teaching: 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 (I 4).

These concrete examples of teachers and developer teachers being able to network and engage in sharing expertise in various ways highlight the teachers’ role as designers of their practice environment, to successfully establish the use of ICT (Pipek & Wulf, 2009). In teachers’ accounts, the use of the shared devices foregrounded the dynamicity of interaction among teachers and pupils reflecting a balanced interaction order between participants. Special challenges are met when teachers need to adjust their own choices and schedules with those of the others’. For such collaboration to function smoothly a balanced interaction order related to collegiality is important.

5 Concluding Discussion

Although guided by curriculum objectives on national and local levels, teachers in basic education in Finland are autonomous to choose their educational approaches and solutions, and to engage in trans-forming the school environment in various ways. Therefore, teachers, as influential actors in the infrastructuring of the educational network of a Finnish city, became participants in this study. They had a role in ensuring continuity in infrastructuring with the overall aim of the digitalization of school. They also contributed to infrastructuring through various activities relying on the local settings of the school, including the planning and development of pedagogical practices with ICT.

Focusing the analysis on teachers’ accumulated experiences through the concept of historical body brought forth the historical and anticipatory aspects of infrastructuring. In addition, the concept of interaction order made it possible to examine the social arrangements of the social actors as influential in infrastructuring. The third perspective to the nexus of practice was to examine the circulating discourses in place. A further aspect that guided the study was the ethnographic stance of nexus analysis, which invited the researchers to recurrently ask what was occurring in the field in terms of the social action in focus. Approaching the nexus of practice from the direction of discourses in place, the analysis brought to the foreground three main discourses that were circulating teachers’ participation in infrastructuring (see Figure 1).
The first discourse was related to the curriculum reform assigning new objectives for the use of digital technologies in teaching. Teachers were contemplating their experiences, understandings and practices (historical bodies), thus engaging in identity work as pedagogical professionals. Their accounts involved an evaluation of the pedagogical benefits of the use of ICT for ensuring the learner’s best, as well as their own digital skills and development of digital competencies. For balancing between the traditional and new educational solutions, teachers were aligning their pedagogy-driven practices with the curriculum objectives drawing on their historical bodies. These situated design activities were aiming to ensure continuity in infrastructuring (Pipek & Wulf, 2009; Star & Ruhleder, 1996). Tensions between local and global aspects of infrastructuring (Star & Ruhleder, 1996) caused by the changes in the educational environment and the organizational conventions of the school were also voiced in a concerned tone. On the other hand, teachers’ accounts reflected how the new curriculum had given policy-level legitimation for their potential for anticipating the use of ICT and visionary pedagogical approaches with ICT. For infrastructuring research, this discourse provides an important contribution. It highlights the teachers’ situated design practices as infrastructuring activities (Pipek & Wulf, 2009; Ludwig et al., 2018) as indeed arising from their reconsideration of current infrastructural use and recognition of potential educational innovations (Pipek & Wulf, 2009). However, when considering who was taking responsibility for putting the innovations forth, there was variation between teachers in terms of their agency. In their discourses, the teachers depicted themselves in some cases as submissive, while in others as empowered actors. This suggests differences in the interaction orders at work in the schools entailing different relational power structures between staff members.

The second discourse concerned infrastructuring activities for establishing the pedagogical use of ICT successfully (Pipek & Wulf, 2009). The discourses in place foregrounded contemplations on continuous professional development for constructing digital competences to enable teachers’ empowered agency with ICT. Building ICT competence was displayed as teachers’ infrastructuring activity (Pipek & Wulf, 2009). Approaching the analysis through the lens of historical body revealed how teachers were embracing both a troubled and an empowered stance to the pedagogical use of ICT. For renewing educational practices, teachers performed situated infrastructuring design activities (Pipek & Wulf, 2009) of evaluating, selecting and balancing the pedagogy-driven use of ICT 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 as resonance activities (Pipek & Wulf, 2009; Ludwig et al., 2018) for sharing expertise on the pedagogic use of ICT. Thus, this research acknowledges the resonance activities as observing and communicating aspects of infrastructuring (Pipek & Wulf, 2009). Considering the interaction order, the teachers’ discourses highlighted the reliance on local ICT support and training in situated use of resources. The traditional interaction order among school actors seemed to persist in the teachers’ expectations for strategically managed leadership: in-service education and enabling practices.
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 were making their ICT choices due to availability instead of pedagogical goals, which reflects an infrastructural breakdown (Star & Ruhleder, 1996). Thus, teachers were balancing their individual educational practices with the social practices and organizational infrastructures in their school, aligning with their institutional culture emerging from the inter-relationships among staff (interaction order). Furthermore, the discourses in place pointed out the teachers’ situated ICT maintenance practices in daily use for ensuring infrastructural continuity (Star & Ruhleder, 1996). Moreover, the teachers’ collegiality in developing new conventions for coping with limited organizational ICT resources foregrounded their anticipations in infrastructuring. Thus, in line with the literature, the teachers balanced with the controversial infrastructure activities (Björgvinsson et al., 2010, 2012a).

The collaboration and sharing of knowledge among teachers’ collaborative resonance activities (e.g., Pipek & Wulf, 2019; Ludwig et al., 2018) were accounted for as empowering teachers’ design activities. The findings of this research on teachers’ reliance on distributed expertise and collegiality emphasize collaboration being an influential aspect in infrastructuring (e.g., Pipek et al., 2017.). These findings also refer to the interest in infrastructuring and collaborative design in the field of Participatory CSCW (Pipek, Karasti & Bowker, 2017; Karasti et al., 2018.) and collaboration in considerations of infrastructuring as social innovation (Björgvinsson et al., 2010). Similarly, the teachers brought up enabling practices arranged by headmasters 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 their local networks in the matter.

This study provides implications for research and practice. Methodologically, it contributes to earlier research on participatory infrastructuring. The choice of a nexus analysis as a strategy to examine infrastructuring comes close to PD ‘in-the-wild’ in the context of school reform, e.g., as a natural part of infrastructure building (see Karasti & Syrjänen, 2004). Teachers’ local infrastructuring activities (e.g., Pipek & Wulf, 2009) included the building of digital competences, maintaining the continuity of infrastructuring as well as balancing the organizational infrastructures, sometimes controversial (e.g., Björgvinsson et al., 2010, 2012a). These implications of the infrastructuring activities of the users responds also to the current calls on practices of participatory infrastructuring for expanding the scope of related design activities and participants (e.g., Böckker, Dindler & Iversen, 2017). By acknowledging this, the nexus analytical concepts provide a valuable insight into power-related aspects, in this case informing the participation of practitioners and their contribution to infrastructuring. Furthermore, the use of historical body as a tool sensitized the 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 inform the balancing of the local-global scales (Karasti, 2014). The conception of social action as an intersection of historical body, interaction order and discourses in place allows a close look at sociocultural histories and social arrangements contributing to infrastructuring (Scollon & Scollon, 2004). Through “infrastructural inversion” (Bowker, 1994), these tools of nexus analysis foreground the transparent, background, and historical elements of infrastructure (Star & Ruhleder, 1996). The existing literature emphasizes the distancing of the notion of infrastructuring from professionalized design. Instead, infrastructuring is seen to include various people as “users” and “designers” (Björgvinsson et al., 2010, 2012; Karasti, 2014; Karasti & Baker, 2004; Karasti & Syrjänen, 2004, 2008; Pipek & Wulf, 2009). Therefore, this research contributes to IS research by offering nexus analytic tools to explore the often backgrounded infrastructural activities of the practitioners involved in infrastructuring.

From a practical perspective, an important aspect to consider is related to teachers’ agency and digital competences. When the educational network and schools develop practices of leadership and collegial support, this may provide a fruitful platform for teachers’ in-service training locally, in the workplace, and enhance their empowerment to meet challenges in situ. The digitalization of schools requires opportunities for teachers to strengthen their digital competences as part of their continuous professional development, as an important activity in infrastructuring.

As for the limits of this study, a broader range of research materials (video recordings and observations from in-situ encounters in the study context) would be fruitful for understanding the phenomenon under study thoroughly. A more detailed look at the dimensions of social action and related discourses is needed to gain a fine-tuned picture of the dynamics and intricate arrangements of relationships. However, the analysis of interviews from a discourse perspective here is more valuable to achieving a deeper
understanding of the role of the teachers as actors and of their interactions in the infrastructuring of the educational network. As diverse research material was collected through a collaborative research intervention with teachers, possibilities for further research are plentiful.

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