Association for Information Systems
AIS Electronic Library (AISeL)

INFRASTRUCTURING IN THE FUTURE SCHOOL CASE - INVOLVING BOTH ADULTS AND CHILDREN

Eija Halkola
University of Oulu, Oulu, Oulu, Finland, eija.halkola@oulu.fi

Netta Iivari
University of Oulu, Oulu, Finland, netta.iivari@oulu.fi

Follow this and additional works at: http://aisel.aisnet.org/ecis2014

INFRASTRUCTURING IN THE FUTURE SCHOOL CASE – INVOLVING BOTH ADULTS AND CHILDREN

Complete Research

Halkola, Eija, University of Oulu, Oulu, Finland, eija.halkola@oulu.fi

Iivari, Netta, University of Oulu, Oulu, Finland, netta.iivari@oulu.fi

Abstract

Information infrastructure building efforts have entered both research literature and the practice of utilizing information and communication technology (ICT) in organizations as well as in our everyday life. The concept of infrastructuring has also challenged the traditional, project-based assumptions of information systems (IS) development. This study will explore infrastructuring within the educational network of a Finnish city. The study examines infrastructuring in-depth in a novel context, and includes an unusual group of participants: children that have so far been almost entirely neglected in IS research. A research framework of nexus analysis, combining both qualitative and participatory research approaches, was utilized for exploring infrastructuring in this Future School case. The study characterizes a multitude of actors, both adults and children, their various activities, and the versatility of outcomes involved. This study addresses both 'design for use before use' and 'design in use' carried out by teachers and pupils. In addition, the existence of certain kinds of resonance and design-for-design-in-use activities is revealed. The study expands infrastructuring to concern both pedagogical, architectural, and interior design, as well as enabling issues; the study reveals that when creating novel learning environments, all these aspects may play a role together with ICT.

Keywords: Infrastructuring, Information Infrastructure, Participation, Children

1   Introduction

Information and communication technologies (ICT) play a pertinent role in our everyday life, including both work and leisure. However, Information Systems (IS) research has mainly concentrated on the context of work; few studies have examined the pertinent role ICT plays at home and during leisure time. Moreover, user groups such as families and children have not been studied nearly as extensively as workers. (Kyng 2010, Vodanovich et al., 2010) Our study addresses the role of ICT in the everyday life context of school, including children as one important user group. In such a setting, a large-scale information infrastructure (II) building effort is examined. Large-scale IIs have also entered the research literature and the practice of utilizing ICT in organizations and in our everyday life. In IS research, there has been a growing interest in understanding such large-scale efforts. Calls for challenging the traditional assumptions of IS projects having clear starts and ends (Orlikowski, 1996) and for more appropriate conceptualizations of the ICT artefact for such large-scale efforts (Orlikowski and Iacono, 2001) have emerged.

Existing research has already characterized the design of such IIs as a highly complex, continuous, evolving process (Hanseth, 1996; Star and Ruhleder, 1996; Star and Bowker, 2002) introducing the concept of infrastructuring (Björgvinsson et al., 2010; Karasti and Baker, 2004; Le Dantec and DiSalvo, 2013; Pipek and Wulf, 2009; Star and Bowker, 2002). This paper will examine such infrastructuring within the educational network of a Finnish city. The case involves participation of various kinds of stakeholders, including the educational authorities of the city, local schools (teachers, headmasters, and pupils), and researchers, as well as local and global companies. This paper will, through the concept of infrastructuring, examine the design and redesign of a complex socio-technical system. The study contributes by examining infrastructuring in-depth in a novel context, including an unusual group of participants: schoolchildren that have so far been almost entirely neglected in IS research (except in Halkola et al., 2012, Halkola et al., 2014). This study explores the research question of 'how can one characterize infrastructuring in the school context?' and contributes through revealing the variety of participants as well as the activities and objects of design.

The paper is structured as follows. The following section defines the concepts of information infrastructure and infrastructuring. The third section presents the research method utilized in this study and the procedures of data gathering and analysis. The fourth section presents the empirical results, while the fifth section discusses their implications and limitations and identifies paths for future work.

2   Information Infrastructures and Infrastructuring

This section introduces the concepts of information infrastructure and infrastructuring.

2.1   Information infrastructure

In the existing literature, the concept of II has been characterized from different perspectives. Some of the most salient definitions are discussed next. Hanseth (1996; 2010) defines II as a shared, open, standardised, heterogeneous, socio-technical installed base in transformation and emphasizes that IIs are large and complex systems involving significant numbers of independent actors, developers, and users. Star and Ruhleder's (1996) notion of infrastructure stresses the relativity and the socio-technical nature of infrastructures. They see infrastructure as evolving while locally-tailored technologies become interweaved with the elements of formal infrastructure. Infrastructure is thus shaped by the conventions of community practice, which are adapted to existing infrastructures, i.e. these elements are intertwined, shaping each other. In organizations, the locally-tailored applications and repositories begin to interweave with the formal infrastructure to create a unique and evolving hybrid. Thus, the

emergence of a transparent, supportive infrastructure is organic and evolves in response to community evolution and adoption. As the IIs have to support current conventions in local organizations, they also have to be changeable in order to support the evolving practices and use. An infrastructure emerges when the tension between local and global is resolved, and local practices are influenced by larger-scaled technology, which can then be used in a natural, ready-to-hand fashion. (Star and Ruhleder, 1996.)

The relevance of stakeholder participation has been acknowledged in the recent literature on II, although the literature has mainly concentrated on the designer's perspective (Hanseth and Lyytinen, 2010). On the other hand, Star and Bowker (2002) consider the Scandinavian school of Participatory Design (PD) as successfully responding to the challenges regarding the socio-technical design process as well as the political and ethical concerns in the design of II. Neumann and Star (1996) have also considered the possibility of applying the design principles of PD in II building. Karasti and Syrjänen (2004), moreover, have explored PD by non-professional designers 'in-the-wild' in two communities. Additionally, recent research by Michener and colleagues (2012) describes the design of an infrastructure where ongoing evolution has been based on the combined approaches of participatory and user-centered design. Furthermore, Twidale and Floyd (2008) propose that there are possibilities supporting both top-down design of infrastructures, (using traditional PD techniques to enable rapid development, testing and reflection on use), and bottom-up design of infrastructures, where end users assemble resources to create a lightweight, ad hoc environment to support collaborative interaction.

Pipek and Wulf (2009) outline a design approach for supporting users' contributions to work-infrastructure improvement. They attribute to work infrastructure all of Star and Ruhleder's (1996) characteristics of infrastructure, while they also share the perspective of work-oriented infrastructures created by Hanseth and Lundberg (2001). Hanseth and Lundberg (2001) recommend such systems be designed and implemented primarily by their users based on their actual use of the technology, and therefore always consider users to be "designers". Pipek and Wulf (2009) approach the improvement of work infrastructures as creative activity that can be described as design. While the actors in the processes of work-infrastructure improvement may be professional designers, they basically consider everybody involved in these processes to be actors performing a deliberate, creative activity directed toward a lasting improvement. Especially, they maintain that the understanding or improving of infrastructures requires the integration of creative activities of the ordinary user. With regard to development activities, Pipek and Wulf (2009) suggest adopting a broader view, including activities such as preparatory design work, and preparatory work-development activities, as well as infrastructural background work that can take place either in technology development or the work-development sphere, which has a more strategic nature. They also discuss resonance activities that involve observation and communication aspects of the infrastructure. Through such resonance activities, the social appropriation of certain technology usages can be captured. For organizing user participation, they introduce the concept of use discourse environments that support users in negotiating the configuration of these infrastructures. The use discourse environments provide users with a communication platform embedded in the relevant infrastructure. These provide means to articulate and visualize issues that permeate infrastructure use and configuration and also provide the means of organizing these communication and negotiation processes. (Pipek and Wulf, 2009.)

2.2   Infrastructuring

The concept of infrastructuring has also been brought up in the research literature as appropriate for characterizing the building and evolution of IIs. Star and Bowker (2002) emphasize the tentative, flexible, and open character of the design process of infrastructures. Karasti and Baker (2004) relate the notion of infrastructuring to ecological information management as an ongoing design process. They argue for design in infrastructuring, "i.e. how to design for the blurring of borders between use and design, for ongoing changes, ease of maintenance, and tailoring of flexible and adaptable systems"

(Karasti and Baker, 2004: 9). Pipek and Wulf (2009) also consider a strict separation of design and use as well as the term design problematic, as it focuses on an artefact that should be designed neglecting the surroundings into which the artefact is placed. Instead, they prefer the notion of infrastructuring in order to distinguish from the notion of design, referring to professionalized design activities. Infrastructuring, understood as reconceptualising one's own work in the context of existing, potential, or envisioned IT tools, is a natural part of every user's activities. Large subsets of these activities are not delegable to some management level or the next professional design process. (Pipek and Wulf, 2009.)

The concept of infrastructuring has been argued as being the current frontier of PD (Clement et al. 2012). There has been a shift of PD from the traditional concerns of work-oriented, productive activities to public spheres and everyday life. This shift to a new milieu, i.e. open public spaces rather than within an organization, also entails a reorientation from "democracy at work" to "democratic innovation". By the same token, there is a movement away from "projecting" and towards the processes and strategies of "infrastructuring". (Björgvinsson et al., 2010.)

Ehn (2008) distinguishes two PD approaches: traditional, with the focus on designing for use before use, and meta-design, as designing for design after design. Hence, there will be a shift in focus from design aiming at useful products and services, to design aiming to create good and useful environments. This will, at project time, lead to a focus on identifying, designing, and supporting social, technical and spatial infrastructures that are configurable and potentially supportive of future design in everyday use. The focus should shift from involving users in the design process towards seeing every use situation as a potential design situation (i.e. design 'at project time', design 'at use time' and design-in-use after design as the overall design project). The challenge and object of design for professional design at project time is the design of such things that can become objects of design-in-use, 'infrastructuring'. (Ehn, 2008.)

Therefore, as presented by Le Dantec and DiSalvo (2013), infrastructuring can be seen as an ongoing process which should not be seen as being delimited to a design project phase in the development of a free-standing system. Le Dantec and DiSalvo (2013) remark how the idea of infrastructuring through design employs a distinction between PD concerned primarily with design-for-use, centered on useful systems, and PD focused on design-for-future-use, structured to create fertile ground sustaining a community of participants. This entails a shift from treating designed systems as fixed products to treating them as ongoing infrastructures. Infrastructuring, then, can be conceptualized as the work of creating socio-technical resources that intentionally enable adoption and appropriation beyond the initial scope of the design, a process that might include participants not present during the initial design. (Le Dantec and DiSalvo, 2013) Björgvinsson et al. (2010), based on the literature (e.g. by Karasti and Baker, 2008; Twidale and Floyd, 2008; Pipek and Wulf, 2009), distinguish infrastructuring thus entangling and intertwining potentially controversial 'a priori infrastructure activities' (like selection, design, development, deployment, and enactment), with 'everyday design activities in actual use' (like mediation, interpretation, and articulation), as well as 'design-in-use' (like adaptation, appropriation, tailoring, re-design, and maintenance).

Based on the literature presented above, we view infrastructuring broadly as reconceptualising one's own work in the context of existing, potential, or envisioned IT tools, a natural part of every user's activities (Pipek and Wulf, 2009). However, we acknowledge also the need for 'design for use before use' taking place 'at project time', not only 'design-in-use' after design in the design project, i.e. "infrastructuring" (Ehn, 2008). Design-in-use includes various kinds of activities such as tailoring, configuring, appropriating, and negotiating (Pipek and Wulf, 2009). Moreover, we acknowledge both technology and work related developments (Pipek and Wulf, 2009). Furthermore, we interpret that design may concern social, technical and spatial aspects (Ehn, 2008), thus we include also design of the 'surroundings' (Pipek and Wulf, 2009) into our analysis. Additionally, we acknowledge resonance activities that involve observing and communicating aspects of infrastructure, through which activities

related to the appropriation of certain technology usage can be captured (Pipek and Wulf, 2009). Inspired by Pipek and Wulf (2009), we emphasize the importance of users articulating, negotiating and visualizing issues that permeate the use and configuration of infrastructure. Finally, in our case, interesting observations relating to designing for design after design (Ehn, 2008) emerged in the sense of some parties creating solutions as support for such infrastructuring activities.

3   Research Design

In this study, the research framework of nexus analysis is relied on. Nexus analysis takes social action as a theoretical center of study. The first and final problem of a nexus analysis is to discover the social actions and social actors which are crucial in the production of a social issue and bringing about social change. Social action or meditated action is any action taken by an individual with reference to a social network. (Scollon and Scollon, 2004: 11.) Nexus analysis was seen as a fruitful choice in the study of a complex process, as it assumes that broader social issues are ultimately grounded in the micro-actions of social interaction, but on the other hand, the most mundane of micro-actions form a nexus through which the largest cycles of social organization and activity circulate (Scollon and Scollon, 2004). Nexus analysis allowed us to focus on micro-actions in the actual infrastructuring effort, while it also forced us to recognize the connectedness of small-scale development efforts with the wider context, the entire II building effort (Halkola et al. 2014). Nexus analysis allowed us to extend the perspective from the actual here-and-now situation to wider cycles of discourse on a long-term basis (Iivari, et al., 2014), as one of the central tasks in Nexus analysis is to examine how "the broad discourses of our social life are engaged (or not) in the moment-by-moment social actions of social actors in real time activity" (Scollon, 2001: 139). Nexus analysis includes three cycles within which the researcher enters the community being researched (engaging), explores it through various methods and data (navigating) and finally, by participating in the practices, is involved in changing them to solve a social issue or problem (Scollon and Scollon, 2004). Nexus analysis was considered as a highly useful research strategy as it allowed us to combine both qualitative and participatory research approaches; engaging and navigating the nexus of practice led us to organize a participatory intervention for children in the effort – i.e. move to change the nexus of the practice in question.

This case concerns the educational network of a Finnish city, within which there has been an ongoing effort to construct a Future School concept and related II building. The educational network refers here to local schools and the municipal, educational administration. The development effort itself spanned the years 2007–2010 and was in progress over the years 2009–2010 during our data gathering. The process was initially started within the local educational administration, collaborating with two pedagogical groups founded to plan guidelines for associated projects. Representatives of the local educational authorities were invited to these groups including headmasters and teachers. Furthermore, in the initial stages of the process, teachers and headmasters of the schools in the district were invited to participate in a 'Future School programme' to develop school culture and to look for the best practices in pedagogy and technology use. Based on their applications for the development projects, ten schools were shortlisted as 'Smart Schools', i.e. pilots in technology use and renewal of pedagogic practices, while at the same time advancing their local, school-level goals and activities. One of the schools, a so-called 'Integrated Pilot School', which was under construction in a new town area, was selected to become a pilot to be equipped with new pedagogical practices and technologies. Examples of the best practices from the Smart Schools were to be exploited in the Integrated Pilot School and later to be extended to other schools in the city and the whole country.

On the basis of the broad discourses survey (Scollon and Scollon, 2004) the most important participants in the nexus of practice, either due to institutional status or media representation, were identified. Those participants were selected as interviewees of this study. Two of the interviewed key actors were project managers (interviewee 2 and 3) in the future school development endeavour, two were headmasters of the involved schools (interviewee 1 and 5), and one a city level development

manager (interviewee 4). The research data also included interviews with two Smart School teachers (interviewee 6 and 7). The two project managers (interviewee 2 and 3) had been initiating the Future School development effort and were continuously collaborating with one of the headmasters (interviewee 5). They collaborated also with the other interviewed actors. Both of the project managers (interviewee 2 and 3) had commercial backgrounds in addition to being experienced in learning environment development. They also were experts in the pedagogical field as teachers, and one of them was also an administrator (interviewee 2). The two Smart School teachers (interviewee 6 and 7) had pedagogical backgrounds and the enthusiasm to experiment with new pedagogical models combined with ICT. The city level development manager (interviewee 4), in addition to education administration, had strong experience also in the pedagogical field. Furthermore, this key actor had also acted as a guiding teacher for other teachers of the city through curriculum work in general. This key actor strongly emphasized the equality aspects of education also calling for sustainable solutions in Future School technology developments.

The Future School development effort was discussed in interviews based on prepared themes of the background, history, and nature of the effort. Also discussed was collaboration between the public, business, and research sectors, building the ICT infrastructure and technology use, community aspects, future visions, and purchasing and acquisition related topics. In addition, the research data contained a huge amount of documentation related to the Future School concept and the II building effort (e.g. minutes, city web portal pages, project pages, various reports, newspaper and magazine articles, and material produced by the involved schools). The interviews and the collection of the other material occurred as part of 'engaging' the nexus of practice, when the researchers were looking for attachment points with the various social actors in the effort.

Additionally, research material has been collected with children during the development of the Integrated Pilot School in collaboration with the City. Children were allowed to participate through a research intervention that aims at changing the nexus of practice: gathering expectations as well as development ideas of the children related to the Integrated Pilot School as part of the community centre. The participants were living in the housing area or they were likely to change to the forthcoming Integrated Pilot School. The results of this intervention were distributed widely to the responsible persons at the Integrated Pilot School to act as feedback and input during the development, and to the public. The research material was gathered in interviews with 24 children and workshops with 15 children. The themes considered in these interventions included: home, school, multipurpose center, community participation and ICT. Interviews also gave the opportunity to discuss themes suggested by the interviewees: their wishes and expectations concerning the Integrated Pilot School in the multipurpose center. Three workshops were arranged: one with 5 children aged 7-8 and two with 5 children aged 9- 12. Design of the workshops was based on the work by Druin and colleagues (2001) and Scaife and colleagues (1999). Methods in the workshops included games, playing (well-known children's plays with questions about ICT), developing ideas, and planning collaboratively.

The study then continued as 'navigating' the nexus of practice concerning the analysis of the material gathered. The analysis was started with the documentation gathered and with the interview data from adults. Initially, the analysis focused on discourses circulating around. The analysis proceeded through a succession of data-driven stages. In the first phase, the researchers worked on the data making initial observations and becoming acquainted with the data. Next, an in-depth analysis was made on one of the key-actor interviews mapping the topics discussed by the interviewee and discourses that emerged in the course of the talk. In the following phase, the analysis was extended to the rest of the interview data of the key actors (see Halkola et al. 2012). Thereafter, the results of the analysis of the data were connected with Star and Ruhleder's (1996) dimensions of IIs (see Halkola et al. 2014). For this paper, the concept of infrastructuring was adopted. The analytic lens introduced at the end of section 2, iteratively emerged by going through the data and the theory. The analysis first considered all the participants involved, after which the objects of 'design' in the effort were examined. Thereafter, the nature of the activities of the involved parties was characterized. The documentation collected and the

interview data concerning the adults as well as the interview and workshop data gathered with children were all examined from these perspectives, resulting in a characterization of participants, their activities, and the objects of design involved.

Ethical aspects relating to children's participation have been considered in relation to this study. Parents were asked permission for children to participate in the interviews and workshops. The activities engaging the children and their elected representatives in their schools have been conducted as part of their school work, the existing structures allowing participation. The activities have been conducted under the supervision of the educational authorities of the City and the representatives of the involved schools (teachers, headmasters). Due to their professional backgrounds, these people are aware of children's ages, developmental stage, and related issues involving children.

4   Empirical Insights

As mentioned, in this study there are ICT companies invited to provide ICT for the Smart Schools. In the pilot projects, ICT solution suppliers have provided expertise and ICT solutions for use in the schools, i.e. they have 'designed for use before use' (Ehn, 2008). The architectural, interior, and pedagogical designs have co-evolved with ICT solutions introduced into these settings. Throughout the schools of the City, a virtual learning environment has been introduced that brings to students' use a calendar, e-mail, online storage space, instant messaging and video conferencing. Otherwise, there are differences among the schools. In one of the Smart Schools, for instance, all teachers and pupils in the third grade have the use of personal laptops. Two classrooms have been equipped with electric socket pillars enhancing working with the laptops. Also the lobby and corridor at the school have been designed and renovated as learning environments equipped with learning technologies to support the experimenting of pedagogical practices. In another Smart School, the hall of the school and two classrooms expanding to corridors have been renovated and equipped with learning technologies to form a learning environment named as 'the innovative hall'. The constructed classrooms are planned to support co-teaching practices and sharing of teachers' expertise. In addition, the innovative hall is to provide a modifiable learning environment with ICT also for the non-formal use of school children as well as for other users of the school building. The innovative hall includes a stage for presentations, performances, and exhibitions of students' project works. The stage is equipped with technologies such as a projector and a projection board on the wall, as well as with space for technologies and sound reproduction equipment under the stage. The interior design in the hall has been designed modifiable, including seats available to be used in school meetings, performances, breaks during the school hours, and also for other users of the building. (Background documentation)

Moreover, the Integrated Pilot School is boldly argued to be designed to support reform of school work. Building of the Integrated Pilot School was based on the winning architectural plan for a school in an architectural competition. The interior design solutions were planned to be flexibly movable to support emerging learning needs. The starting points for the architectural plan were sense of communality, co-operation and flexibility. The Integrated Pilot School was especially planned in response to the needs of the 21st century learner both in regard to the spaces and the level of equipment. In the Integrated Pilot School the starting points for interior design are 'learning cells' including both home classrooms and shared classrooms. The classroom spaces are planned to be able to open flexibly in order to enable collaborative teaching. As for the technology infrastructure, in addition to whiteboards, teaching equipment in the classrooms includes smart boards with facilities to download information as presented in the classroom computer. Furthermore, the ICT solutions in the classrooms enable teachers to send the learning materials, also notes made on the smart board, to pupils via e-mail. Teachers utilize laptops, video projectors, and video cameras in teaching. The first and second graders work in groups with shared desktops. All teachers and pupils from the third grade up have their own personal laptops. Not only the learning environments of the new school, but also the school yard, have been equipped with modern ICT. (Background documentation)

4.1 Architectural and interior design solutions intertwined with ICT

As has already become evident, in this case there has been considerable focus on architectural and interior design as part of the infrastructuring. The development efforts have varied from new schools to be built to old schools to be renovated and furthermore, to schools aiming to create new models of operation. Interior design and architecture have been considered essential in constructing innovative learning environments for the Smart Schools. Architectural evaluations of the Smart Schools have been conducted to provide a basis for the development plans: *"We have carried out architectural rounds, reviews, based on which these architectural designs of the environment of the 21st century have been created."* (Interviewee 2) Interior solution suppliers have also been testing the furnishing in the learning environments in the Smart Schools: *"With the interior solution suppliers, we have test furnished these target places (...) and we think together what kind of the furniture of the future learning environments will be."* (Interviewee 2)

The architectural and interior design aspects of II have been planned in co-operation with various kinds of educational experts. These professional spatial designs have been planned to support the new pedagogical models, but also to leave possibilities for design-in-use through flexible solutions and responsiveness to emerging needs. In addition, resonance activities have been organized, allowing teachers and pupils to articulate and negotiate issues around the infrastructure. The Smart School teachers and pupils were invited to comment on the architectural plans and the selection of the learning technologies in arranged meetings: *"For example, when this plan for the future school classroom was being done with the architect's office for the upper concourse, (...) so we had pupils with us [in the architect's office] and this completed plan was taken to them for comments: what they think it looked like and what benefits it would have."* (Interviewee 1) *"Well, in these joint meetings when the premises have been planned and put into practice, at regular intervals, the representatives of the student council, representatives of children, and representatives of pupils have been present in planning meetings."* (Interviewee 2) Teachers had invited student councils in the process:*"I am the guiding teacher of the student council and took the pupils into the process. (...) We have, together with pupils, considered what we needed and how the equipment will be used."* (Interviewee 7) *"Where these architectural rounds have been made, children have also been listened to. And [a school] has especially excelled in this; there is a well-functioning student council. So that there these drawings and plans have become commented by the student council (...) of course the teacher was there as a guide (...) very good comments were gained"* (Interviewee 2)

4.2 Pedagogical solutions intertwined with ICT

The planned infrastructural aspects of architectural, interior design and ICT solutions have required teachers' pedagogical expertise for grounding the solutions to the local Smart Schools' settings and practices. Educational administrators and especially some teachers of some Smart Schools have participated in the development projects as pedagogical experts: *"We maybe have a more pedagogic orientation to what should be done with the equipment. There is no point in ordering here a huge number of screens if we have nothing to present. (...) First of all, we [three teachers] have together in this group designed everything, made these activity descriptions and planned what is needed for these different activities possible. We approach it so that we have made very detailed descriptions of all the situations, learning situations and some other school related situations."* (Interviewee 7)

The Future School ideology positions the learner as an active agent and a researcher who participates in collaborative knowledge creation in a group. ICT applications are expected to create new innovative possibilities to support collaborative learning and knowledge building. (Background documentation) The constructed learning environments for the Smart Schools have been planned to support the utilizing of ICT solutions enabling both collaborative and learner-centered work practices as well as personalization of teaching. The teachers have developed learner-centered, personalized e-learning

materials for the digital learning environments: "*I make quite a lot of material myself (...), which is then modified according to the pupils, so that there is this individual consideration of different kinds of learners.*" (Interviewee 6) The use of e-learning materials with personal laptops has also been used to support learner-centered, personalized learning "*We have these personal PCs in use; it indeed changes the nature of teaching a lot. We can consider the pupils so that the one who is not capable of reading that much can listen, and the one who cannot write that much can produce speech with the computer and enliven the stories this way. (...) We have a lot of boys who did not like to write at all. They refused to write stories, but as it happens, with a computer it is a bit nicer to write, illustrate, and create voice.*" (Interviewee 6) Pupils' collaborative knowledge creation has also been supported with pedagogical practices intertwined with ICT: "*Now we have laptops here, and we can simultaneously share the same work in real-time. (...) It is this kind of sharing.*" (Interviewee 6)

Furthermore, the constructed learning environments with ICT solutions have been envisioned to support new pedagogical models such as simultaneous (co-teaching) and cross-grade teaching (no division to classes according to age group). The teachers of the Smart Schools have been encouraged to develop as well as to experiment with such pedagogical models and practices intertwined with ICT: "*The whole age group was in one large group, two teachers, who between themselves, very freely started planning how to do things with that grade, how to divide them into groups, in which subjects etc. ... the aim was to start working at the beginning of the autumn term so that each [pupil] would have had a personal TabletPC of his/her own.*" (Interviewee 1) Instead of detailed preplanning, the development work has been flexible for enabling adjustments and characterized as evolving. "*We haven't had, and we cannot have had, such a detailed preliminary model of how we will proceed, but we have sort of created it in the course of the process.*" (Interviewee 1) The available ICT solutions have clearly shaped the teachers' pedagogical practices. The teachers have also actively appropriated ICT, intertwined with their pedagogical practices. Experienced teachers have also helped their pupils to appropriate the adopted technologies as part of their school work. Moreover, the schools and teachers have also exercised influence on the technologies adopted. For instance, concerning the new virtual learning environment that had been adopted in the City, an exception was made in one of the Smart Schools that was allowed to continue using the current virtual learning environment, as it contained personalized e-learning materials to be used with the laptops. Moreover, the development projects in some cases have even been initiated by the teachers and pupils of the schools: "*The whole idea has actually been initiated by us [teachers and pupils] originally so that this is not such an external idea (...) there is a long continuation of this, we have wanted continuously to improve the level of technology and the learning environment also.*" (Interviewee 7)

The development projects have also made these facilities available for other teachers not directly participating in the development projects. The pilot projects have been recognized as "*bringing good to the entire school*" (Interviewee 6). The teachers, in their communities, have shared their experiences of experimental teaching with ICT. This has encouraged other teachers to appropriate ICT with new pedagogical practices as well: "*The use of these technologies is possible, and interest and willingness has now awakened among other teachers to change teaching methods and expertise.*" (Interviewee 6) In addition, teachers' participation and more general awareness of the objectives of the Future School program have been promoted through in-service education. In one of the Smart Schools, weekly meetings with mentors have been arranged to support teachers' appropriation of ICT in their teaching: "*And every week, the teachers of the third-graders at that time plus the teacher-pair who would start the following year as well as the mentor teachers were meeting (...) discussing where we are and what sorts of plans there are, and what kinds of partners can be engaged.*" (Interviewee 1) Occasionally, teachers' resources have been reserved for planning work and also education of their colleagues to support the use of ICT in their local organization: "*They will take one day to plan (...), depends on how much they need, for three days or as long as a week, when they then discuss the fifth and the sixth grades and wishes concerning the upper grades and also the training of the other teaching staff, and they share positive experiences about technology use*" (Interviewee 1)

Furthermore, teachers of the other Smart Schools have been invited to participate in the arranged planning and training days for sharing of technology use experiences: *"We offer it [training] also to other teachers in the Future School project so that they can come along and pick from there whatever they wish."* (Interviewee 1)

4.3   Enabling solutions supporting infrastructuring activity

In the Smart Schools, new practices have been created for enabling teachers' development work as well. The co-teaching system and its associated development model are examples of enabling solutions created to support and enhance teachers' development work relating to the appropriation of ICT solutions to support pedagogical practices*: "We have, for example, started creating this co-teaching system so that when the goal is to get teaching and learning more learner-centred, and also utilize these teacher strengths, we also strengthen the teachers' wellbeing, and innovation. Those models have sort of been developed during the process."* (Interviewee 1) The importance of involving teachers in the development work has been deemed very important in the effort. *"This our solution aims at, as there are two teachers who support each other during the whole work day. We have noticed that when the teachers do not toil alone their innovativeness increases, coping improves, and work motivation increases."* (Background documentation) Teachers participation in the development work would, however, necessitate additional arrangements, possibly also exposing tensions from the direction of the trade union as explained by the representative of the local educational authority: *"...we could have a more flexible time plan for teachers, but unfortunately this has not been successful ... the teachers' union is quite strong and they don't necessarily always see that even teachers themselves wish the work could be developed."* (Interviewee 4)

The Future School effort has also created an environment consisting of a network of the Smart Schools and some companies collaborating and developing the solutions further than what can be considered as an enabling solution in this infrastructuring effort. For the companies invited to provide ICT solutions the Smart Schools have offered living-lab environments for product development and experimentation in local settings: *"We have trialled it already with these ten Smart Schools, by offering these schools as a kind of development platform for new products, new technologies, and new experiments."* (Interviewee 2) Favourable possibilities for the development work have been arranged by initiating tripartite cooperation with public, research and business sectors for the joint development work: *"On all levels, something has been done – the teaching profession, leadership, physical learning environment, infrastructure, technologies. Within all the sectors something has been done and company collaboration and research collaboration has been launched ..., with these ten Smart Schools we have been busy and have advanced them; their ideas have been enriched and supported. And, these projects have then been established around it."* (Interviewee 2)

Novel recruiting and competence management processes and ICT support have also been developed collaboratively with a global company for the reason of identifying the competencies required of teachers of 'the Future School', where the ideology and the best practices in pedagogy and ICT use are implemented, and for such teachers' recruitment: *"Regarding the teaching profession, we have cooperated with [a global company] and some other agents. We have thought of these competencies of the teachers of the Future School and this whole curve of competence management. We have figured out ready-made models (...) on how to change the recruitment system so that it is based on the personnel plan of the school and on competencies of the teachers of the Future School"* (Interviewee 2) *"Here, related to competence management, they [a global company] have had a strong role. (...) A tool has been prepared for Finnish headmasters (...) there has been an actual tool prepared for recruitment. There are videos for help on how to carry out the recruitment process, as well as related issues such as what questions to address, etc."* (Interviewee 5) Therefore, this aspect involves both an ICT solution and new practices for recruiting teachers suitable for the Future School - equipped with innovative ICT and pedagogical practices - and for managing the competencies of such teachers.

4.4   Children's role

Pupils have also been involved in the infrastructuring activity. Children's appropriation of technologies in learning was supported by their teachers. Mainly pupils have been involved as users of the learning solutions introduced: *"So children's participation in this phase has rather come through content production and projects, like when they have started doing something, let's say a kind of water project they were working on. ... I was following it and I have later been able to see through video how it was completed ... they just got a project topic and started as a group to consider how it would be done and what they would need and who would be involved and so on."* (Interviewee1) The innovativeness of children as 'designers-in-use' has already been acknowledged in this case: as users of the learning technologies, pupils have created new innovative practices: "*… how these schoolchildren, third-fourth-graders, how they, in a way, take part in the use of these devices and programs by sort of inventing most genius shortcuts (...) Children cut corners wherever they can and, well, they often find quite new applications.*" (Interviewee 1)

Moreover, as mentioned, the pupils have acted as informants and testers of learning environments for the Smart Schools. Elected representatives of the schoolchildren have been asked for comments concerning both architectural plans and plans for the selection of specific learning technologies in meetings. Children's participation as testers is related to user evaluations of the learning technologies produced: the pupils have participated in the evaluations of a mobile learning environment and a learning game to be developed. *"This kind of usability information, now <mobile environment> is just one example, another good example of what's been done well is this <learning game>. It was used with fifth-and ninth-graders and pupils in upper secondary grades. And during that half-hour gaming session one saw that it was meaningful; pupils were smiling; everybody had a good time and stuff had been learnt.*" (Interviewee 4)

Additionally, in the interviews and workshop sessions we organized, the children were given an opportunity to innovate how ICT could be used at school and in learning. Most of the children's ideas were quite mundane, reflecting the ICT tools school-aged children have already used. Availability of computer games for learning at school was commonly brought up: *"One goes for example to learning pages"* (Boy, 1st grader). Furthermore, the Internet was commonly brought up: *"You can view on the Internet, some stuff from there ... or, if you get for example environmental information tasks or environmental stuff there from the computer."* (Boy, 1st grader) Use of computers and the Internet was considered as support for assignments at school and with homework: *"for looking for information for example from Wikipedia"* (Boy, 6th grader) *"Maybe so that from [the computer] one could get information on what needs to be done."* (Boy, 1st grader) Utilizing computer was, furthermore, viewed helpful while preparing for exams: *"One could do such things that will be helpful, like for forthcoming exams. One could make notes with [computer], if it is much quicker. Your hand gets tired when you do like this [writing with pen]."* (Girl, 5th grader) Also, mobile phones were viewed usable in learning: *"If there were awfully difficult calculations in math, for that one could use..."* (Boy, 3rd grader) Also the possibility of taking pictures with the mobile phones was considered as useful: *"It would be nice, if one reads some helping text or something like that, one could remember how it was. For example in math, take a picture with the mobile phone, then at home one can look at it and think with the help of it. If one takes a picture of a math exercise, a picture of what was taught at school."* (Girl, 5th grader)

More creative ideas inspired by technology mediated learning, and less influenced by the prevailing pedagogical practices, were also identified from the data. In one vision, the possibility to utilize computers was viewed as inspiring and allowing 'spreading out': *"It would be nice to go somewhere, not necessarily in the class, but (...) spreading a bit out, not necessarily needing to stay at own classroom, but one could be for example in the lobby [of the school]."* (Girl, 5th grader) Moreover, highly imaginary and playful visions such as: "*…a robot that would make the homework, so you would not need to do the homework*" (Girl, 2nd grader), "*such kind of flash drive, which can be placed*

in the ear, and there you can download any material" (Girl, 3rd grader). "*There could be a handy phone that comes to you when someone calls*" (Boy, 1st grader), "*…a television the size of class wall*" (Boy, 2nd grader) were expressed. Children, furthermore, acted as idea creators of pedagogical practices: e.g. "*learning through play*" (Boy, 1st grader) and learner-centred teaching in music: "*one could start, from the grade three, to practice playing guitar*" (Boy, 3rd grader) were suggested. In the workshop with 9 to 12 years old, when asked about the potential of multi-subject teaching, children also identified some interesting possibilities: history and religion: "*Jesus adventures in some history book*", French and domestic science: "*…studying French during domestic science, we could make all the French meals*" and gym and music: "*…you move according to the music*" could be combined.

5   Concluding Discussion

This study explored infrastructuring in the school context where children had been allowed to take part, thus contributing to the extant literature by offering insights on infrastructuring in a novel context, including an unusual group of participants. Table 1 summarizes the empirical results answering the research question of 'how can one characterize infrastructuring in the school context?'

Design	Actors involved
Technical - ICT	Companies: designing for use before use Teachers: design-in-use (appropriation), resonance activities Pupils: design-in-use (appropriation), resonance activities
Social - Pedagogical	Teachers: designing for use before use, design-in-use, resonance activities Pupils: design-in-use (appropriation), resonance activities
Spatial – Architecture and interior	Companies: designing for use before use Teachers: design-in-use (appropriation), resonance activities Pupils: design-in-use (appropriation), resonance activities
Enabling	Headmasters: designing for design-in-use Educational authorities: designing for design-in-use Companies: designing for use before use

Table 1. Characterizing Infrastructuring in the School Context

The infrastructuring effort included both planned and emergent activities and revealed the intimate intertwining of practices and technologies. The planned activities concerned architectural evaluations providing a basis for infrastructuring in the schools and for their innovative learning environments. Planned activities also included the ICT companies' delivery of the specified ICT, adapted to each Smart School setting. As for the emergent activities, the planned architectural, interior design and ICT solutions have all required adaption to the local Smart School settings and practices. Educational authorities with their enabling practices as well as teachers, as pedagogical experts, have experimented with and appropriated ICT intertwined with pedagogical practices. The pedagogical practices have been strongly shaped by the available technology, while the teachers and schools have also been influential in making decisions regarding technology use.

Besides addressing a novel context and unusual user group the study also contributes to the extant literature on infrastructuring through offering novel findings concerning the multitude of actors and the versatility of objects of design involved. In the effort examined in this paper, numerous companies, schools, teachers, headmasters, and pupils have contributed. The solutions produced are in part novel ICT solutions, but also novel architectural and interior designs, pedagogical practices, and practices and ICT solutions enabling partners' continuous developmental work. In this study the evolving II was considered as a complex, socio-technical system into which ICT solutions had been offered by ICT companies that were 'designing for use before use' (cf. Ehn, 2008), while the analytic focus was on the other kinds of solutions that had emerged as the result of, or along with, the adoption of these ICT

solutions. From the viewpoint of IS research, therefore, this study brings up that infrastructuring, at least in this educational context, concerns pedagogical, architectural, interior design and enabling issues – revealing that when creating novel learning environments, all these aspects may play a role together with ICT. Thus, we acknowledge both technology and work-related developments (Pipek and Wulf, 2009), i.e. the technical and the social, as well as the spatial (Ehn, 2008), and we also acknowledge design of the 'surroundings' (Pipek and Wulf, 2009). The existing literature allowed us to broadly examine infrastructuring as reconceptualising one's own work in the context of existing, potential, or envisioned, using IT tools - a natural part of every user's activities (Pipek and Wulf, 2009). However, we acknowledged also 'design for use before use' that provided the starting point for 'design-in-use', i.e. "infrastructuring" (cf. Ehn, 2008). Teachers were very influential as creators of the novel pedagogic practices intertwined with the use of modern ICT, while pupils also appropriated those in their work, i.e. learning at school, and in doing so were also considered as very creative. Additionally, we also acknowledged resonance activities that involved observing and communicating aspects of infrastructure (Pipek and Wulf, 2009). These were interpreted, in the arranged meetings, as contributions by teachers and pupils as commentary on the solutions created. Additionally, teachers shared their experiences more widely in the educational network and gained in-service educational opportunities. Finally, interesting observations relating to 'designing for design after design' (cf. Ehn, 2008) also emerged, in the sense of some parties creating solutions to enable and support such infrastructuring activities. Those included the headmasters and educational authorities making arrangements for teachers' development work, the educational authorities arranging company-school cooperation and the companies, headmasters, and educational authorities developing ICT and practices for recruiting the 'right' kind of teachers for the 'Future School'.

In this case, children were allowed to experiment with novel learning technologies as well as to be invited to provide their comments and insights for various adult-created solutions. Moreover, we enabled them to express ideas for the forthcoming Integrated Pilot School. Our research framework of nexus analysis (Scollon and Scollon, 2004) guided us to changing the nexus of practice by allowing children more voice. It is interesting to observe that the children were capable of conceiving numerous kinds of ICT solutions to support their learning as well as linking those to their learning practices in some cases. Moreover, some children were even able to invent some pedagogical practices, indicating ways they would like to be taught (i.e. through play, by personalizing the teaching). Most of the ICT solutions invented by the children were quite mundane, however, as PCs, mobile phones, the Internet and different kinds of games are already widely in use at schools. This is not a surprise as it has been reported that for children it is very natural to imitate; it is the way human beings learn (Kuure et al., 2010). On the other hand, the children's ideas bear an interesting resemblance to the ICT solutions produced by adults in this case, as it seems that the Integrated Pilot School as well as the Smart Schools very heavily relied on PCs, learning games, and mobile technology. Therefore, not even the solutions produced by the adults were very innovative.

Concerning implications for practice, we suggest that practitioners consider, in their case, whether the spatial aspect, the design of the surroundings, is also relevant – not only technology and work-related developments. Another novel angle for practitioners to consider is the 'designing for design after design' i.e. design for infrastructuring. It is known that 'design for use before use' and 'design-in-use' take place, but in this case, some parties created solutions to enable and support further infrastructuring. Such could also be beneficial in other settings. We also highlight the importance of resonance activities that, in this case, took place during various kinds of meetings and in-service education. As for the limits of the study, although nexus analysis provided us a lens for examining the phenomenon under study from a variety of perspectives, on a macro level, a more detailed look at the dimensions of social action and the related discourses are needed to gain a better picture of the dynamics and intricate arrangements of relationships. The analysis of the interview material from a discourse perspective is also needed to achieve a deeper understanding of the role of the various actors and of their interactions in this large-scale, long-term, infrastructuring effort.

References

Björgvinsson, E., Ehn, P. and P. A. Hillgren, (2010). Participatory design and democratizing innovation. In Proceedings of the 11th Biennial Participatory Design Conference, pp. 41-50, ACM.

Clement, A., B., McPhail, K. L. Smith and J. Ferenbok (2012). Probing, mocking and prototyping: participatory approaches to identity infrastructuring. In Proceedings of the 12th Participatory Design Conference: Research Papers-Volume 1, pp. 21-30, ACM.

Le Dantec, C. A. and DiSalvo, C. (2013). Infrastructuring and the formation of publics in participatory design. Social Studies of Science, 43(2), 241-264.

Druin, A., B. B. Bederson, J. P. Hourcade, L. Sherman, G. Revelle, M. Platner and S. Weng (2001). Designing a digital library for young children. In Proceedings of the 1st ACM/IEEE-CS Joint Conference on Digital Libraries, pp. 398-405.

Ehn, P. (2008). Participation in design things. In Proceedings of the Tenth Anniversary Conference on Participatory Design 2008, pp. 92-101. Indiana University.

Halkola, E., Iivari, N., Kinnula, M., Kuure, L. and Molin-Juustila, T. (2014): A Nexus Analysis of Participation in Building an Information Infrastructure for the `Future School´. In Proceedings of the HICSS, Waikoloa, USA, January 6-9, 2014, pp. 4457 - 4466

Halkola, E., Iivari, N., Kuure, L., Kinnula, M. and Molin-Juustila, T. (2012): Children's Participation in Constructing the Future School: A Study of a Large-scale Effort Involving ICT. International Journal of Social & Organizational Dynamics in Information Technology 2(2), 48-64.

Hanseth, O. (1996). Information Technology as Infrastructure. Gothenburg Studies in Informatics, Report 10, Department of Informatics, Göteborg University.

Hanseth, O. (2010). From Systems and Tools to Networks and Infrastructures - from Design to Cultivation: Towards a design Theory of Information Infrastructures. In Jonny Holmstrøm (ed.), Industrial Informatics design, Use and Innovation, IGI Global, pp. 122 – 156.

Hanseth, O. and Lundberg, N. (2001). Designing Work Oriented Infrastructures. Computer Supported Cooperative Work: The Journal of Collaborative Computing (10) 3-4, pp. 347–372.

Hanseth, O. and Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: the case of building internet. Journal of Information Technology, 25(1), 1-19.

Iivari, N., Kinnula, M., Kuure, L. and Molin-Juustila, T. (2014): Video Diary as a Means for Data Gathering with Children - Encountering Identities in the Making. International Journal of Human-Computer Studies 72(5), 507–521.

Karasti, H. and K. S. Baker (2004). Infrastructuring for the long-term: Ecological information management. In Proceedings of the 37th Annual Hawaii International Conference on System Sciences, pp. 10-pp, IEEE.

Karasti, H., and A-L. Syrjänen (2004). Artful infrastructuring in two cases of community PD. In Proceedings of the 8th conference on Participatory design, ACM Press, pp. 20-30.

Kuure, L., Halkola, E., Iivari, N., Kinnula, M., and Molin-Juustila, T. 2010. Children Imitate! Appreciating recycling in participatory design with children. In Proceedings of the 11th Conference on Participatory Design, K. Bödker, T. Bratteteig, D. Loi, and T. Robertson (eds.), Sydney, Australia, November 29 – December 3, 2010. pp. 131-140.

Kyng, M. (2010). Bridging the Gap Between Politics and Techniques. Scandinavian Journal of Information Systems, 22(1).

Michener, W. K., Allard, S., Budden, A., Cook, R. B., Douglass, K., Frame, M. and Vieglais, D. A. (2012). Participatory design of DataONE—enabling cyberinfrastructure for the biological and environmental sciences. Ecological Informatics, 11, 5-15.

Neumann, L. and S. L. Star (1996). Making Infrastructure: The Dream of a Common Language.In Proceedings of the Participatory Design Conference 1996 (PDC '96), Cambridge, MA: Computer Professionals for Social Responsibility/ACM.

Orlikowski, W. J. (1996). Evolving with Notes: Organizational change around groupware technology. In C. U. Ciborra (Ed.) Groupware & Teamwork, Chichester: Wiley, pp. 23 - 60.

Orlikowski, W. J. and Iacono, C. S. (2001). Research commentary: Desperately seeking the" it" in it research—a call to theorizing the IT artifact. Information systems research, 12(2), 121-134.

Pipek, V. and Wulf, V. (2009). Infrastructuring: Towards an integrated perspective on the design and use of information technology. Journal of the Association for Information Systems, 10(5), 447-473.

Scollon, R. (2001). Action and text: Toward an integrated understanding of the place of text in social (inter)action. Methods in Critical Discourse Analysis (ed.), pp.139-183, London, Sage.

Scollon, R., and Scollon, S. W. (2004). Nexus Analysis: Discourse and the Emerging Internet. London, Routledge.

Star, S. L. and G.C. Bowker (2002). How to infrastructure. In Lievrouw, L. A. and Livingstone, S. (eds.) Handbook of New Media, pp. 151-162, SAGE Publications.

Star, S. L. and Ruhleder, K. (1996). Steps toward an ecology of infrastructure: Design and access for large information spaces. Information System Research 7, 111-134.

Twidale, M. B. and Floyd, I. (2008). Infrastructures from the bottom-up and the top-down: can they meet in the middle? In Proceedings of the Tenth Anniversary Conference on Participatory Design 2008, pp. 238-241, Indiana University.

Vodanovich, S., Sundaram, D., & Myers, M. (2010). Research Commentary-Digital Natives and Ubiquitous Information Systems. Information Systems Research, 21(4), 711-723.