JYU DISSERTATIONS 92

Ari Tuhkala

Participatory Design: an Approach for Involving Teachers as Design Partners

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF INFORMATION TECHNOLOGY

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ABSTRACT

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Finnish summary

Teachers play an important role in preparing students for a fast-moving, globalised, and digitalised world. Research to date on teachers and technology has focused on teachers' skills in using technology and integrating it into learning and teaching. However, the issue is that teachers are often seen as implementors, but are denied the opportunity to influence what is being implemented. Thus, teachers may perceive that they are being forced to adopt technology without proper cause.

To address this issue, this dissertation examines participatory design as an approach for involving teachers as design partners. Previous participatory design studies in educational contexts have focused on students. To expand such research to include teachers, the present dissertation examines the following: For what purpose have participatory design studies examined teachers? How are teachers' goals and concerns manifested through participatory design? What issues can be observed when involving teachers in participatory design? The research design comprises three parts: systematic literature mapping of participatory design studies involving teachers; a project involving teachers from a special education school to design a learning space system; and a project piloting a new subject as an elective course in Danish lower secondary education.

The systematic mapping produced an overview of the current state of research into participatory design involving teachers. Teachers' goals and concerns demonstrated how participatory design contributes to the development of a shared pedagogical vision and communication between political decisionmakers and local teachers. The identified issues in the two projects were connected to findings from the literature mapping to propose three building blocks of participatory design for involving teachers: identifying roles, needs, rights, and responsibilities, positioning participation as a possibility instead of an obligation, and clarifying an agenda for sustainable outcomes. This dissertation thus serves as a foundation for future efforts in involving teachers in decision-making, for example when introducing digital technologies in education.

Keywords: participatory design, design, design-based research, teachers, educators, education, school, technology, digital technologies, digitalisation

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TIIVISTELMÄ (FINNISH ABSTRACT)

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Osallistava suunnittelu opettajien kanssa tehtävässä kehittämistyössä
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Opettajilla on merkittävä rooli kun lapset ja nuoret valmistautuvat yhä nopeammin muuttuvaan, globalisoituvaan ja digitalisoituvaan maailmaan. Aikaisempi opettajia ja digitaalisia teknologioita käsittelevä tutkimus on keskittynyt lähinnä opettajien taitoihin käyttää teknologiaa ja sisällyttää sitä oppimiseen. Opettajat nähdäänkin usein toimeenpanijoina, joilla ei välttämättä ole mahdollisuuksia osallistua päätöksentekoon siitä, miten teknologia kouluihin tuodaan. Opettajat voivat kokea, että teknologian omaksumisesta on tullut heille pakko, jolle ei ole selkeitä perusteluja.

Väitöskirjassa tutkitaan osallistavaa suunnittelua lähestymistapana opettajien kanssa tehtävässä kehittämistyössä. Aiemmat aihepiirin tutkimukset on tehty pääsääntöisesti oppilaiden kanssa, minkä vuoksi väitöskirjassa keskitytään opettajiin. Väitöskirjan tutkimuskysymykset ovat: millaisia tuloksia aiemmat opettajien kanssa tehdyt osallistavan suunnittelun tutkimukset sisältävät, miten opettajien tavoitteet ja huolenaiheet ilmenevät kehittämistyön aikana ja mitä ongelmia opettajien osallistamiseen liittyy? Väitöskirjan tutkimusasetelma sisältää kolme osaa: systemaattisen kirjallisuuskartoituksen opettajien kanssa tehdyistä osallistavan suunnittelun tutkimuksista, oppimistilajärjestelmän kehittämishankkeen Valteri-koulu Onervassa sekä kehittämishankkeen, jossa tutkittiin uutta *teknologiaymmärrys* nimistä oppiainetta tanskalaisissa yläkouluissa.

Systemaattisella kirjallisuuskartoituksella saatiin ajankohtainen ja kattava kuvaus opettajia koskevasta osallistavan suunnittelun tutkimuskentästä. Opettajien tavoitteiden ja huolenaiheiden tarkastelun perusteella osallistava suunnittelu edesauttoi pedagogisen vision muodostamisessa ja toimi viestintäväylänä paikallisten opettajien sekä poliittisten päätöksentekijöiden välillä. Kehittämishankkeissa tehdyt havainnot yhdistettiin kirjallisuuskartoituksen tuloksiin, joiden perusteella väitöskirja ehdottaa kolmea toimenpidettä opettajien osallistamiseksi. Ensiksikin, eri osallistujaryhmien roolien, tarpeiden, oikeuksien ja velvollisuuksien tunnistaminen. Toiseksi, osallistumisen perusteleminen opettajille mahdollisuutena velvollisuuden sijaan. Kolmanneksi, kehittämishankkeen tavoitteiden täsmentäminen kestävien tulosten aikaansaamiseksi. Väitöskirja muodostaa perustan opettajien osallistamiseksi päätöksentekoon, esimerkiksi kun teknologiaa otetaan käyttöön kouluissa.

Avainsanat: osallistava suunnittelu, design, design-tutkimus,
opettajat, kouluttajat, koulutus, koulu,
teknologia, digitaaliset teknologiat, digitalisaatio

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Jyväskylä, 24. May 2019
Ari Tuhkala

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PII Tuhkala, Ari. Participatory Design with Teachers - Systematic Mapping of Studies. *Submitted*, 2019.

PIII Tuhkala Ari, Isomäki Hannakaisa, Hartikainen Markus, Cristea Alexandra, and Alessandrini Andrea. Design of a Learning Space Management System for Open and Adaptable School Facilities. *Communications in Computer and Information Science, vol. 865*, 2018.

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1 INTRODUCTION

Digital technologies such as computers, mobile devices, and software applications are developing rapidly (hereinafter referred to as *technology*) and have a strong impact on societies. This development becomes actualised when tasks that once required human involvement become automated through digital form. A typical example is how the transportation industry is changing dramatically due to the introduction of automatic vehicles. Reducing human error in the operation of aeroplanes, ships, and cars makes transferring goods and people more efficient. Even though this is a positive direction, it raises new challenges: for example, algorithms must now accommodate decisions previously made by professional drivers, the outcome of which can directly impact human life.

Similarly, it is said that education is going through a digital reform. Technology presents both challenges and possibilities for education. The benefits of computers in the classroom, for example, include: *significantly increased academic achievement in science, writing, math, and English; increased technology use for varied learning purposes; more student-centered, individualized, and project-based instruction; enhanced engagement and enthusiasm among students; and improved teacher–student and home–school relationships* (Zheng et al., 2016, p. 24). Realising these benefits, however, does not happen automatically. Rather, it relies greatly on how teachers choose to introduce and implement technology (see Owston, 2007; Wastiau et al., 2013; OECD, 2015; European Commission, 2018).

Previous research on teachers and technology has focused on teachers' ability to use and integrate technology in teaching and learning (Cox, 2013). These skills are defined in technological competence frameworks, such as Technological Pedagogical Content Knowledge (Mishra and Koehler, 2006), digital literacy (Hall et al., 2014), and digital competency (Krumsvik, 2014; Røkenes and Krumsvik, 2016; Kelentric et al., 2017). Some researchers have examined teachers' proficiency in integrating technology (Hsu, 2017), their adoption of new technologies (Aldunate and Nussbaum, 2013; Salinas et al., 2016), perceived usefulness of technology (Scherer et al., 2015; Tondeur et al., 2016), motivations for using technology (Uluyol and Şahin, 2016), and pedagogical beliefs about technology (Ertmer et al., 2012; Mama and Hennessy, 2013; Admiraal et al., 2017).

According to these studies, teachers need to be provided with high quality training, enough time to get adapted to technology, and enough support to pedagogically utilise technology. Moreover, teachers' willingess to use technology increases, if technology gives them positive experiences and aligns with their pedagogical beliefs. In contrast, insufficient time to learn new technologies, the lack of opportunity for professional development, lack of support from colleagues and administration, and negative attitudes towards technology are well known barriers (Owston, 2007; Lawrence and Calhoun, 2013; Mama and Hennessy, 2013; Ng, 2015; Vrasidas, 2015).

Despite the research into the subject, realising the benefits of technology has proven challenging. In Finland, for example, where teachers are highly educated, students perform comparatively well in international tests (OECD, 2016), and people, in general, have a high technology adoption level (Cruz-Jesus et al., 2016). However, there are signs that the negative impacts of technology are overcoming the benefits: *as a teacher, I have had enough of digital hype by consults*[1]; *majority of students, parents, and teachers are getting frustrated with the drawbacks of digitalisation*[2]; and *the use of technology is impairing learning results*[3].

While these reports demonstrate anecdotal evidence, they nonetheless indicate that current ways of introducing technology in schools can be improved. Teachers should be more involved in the processes in which decisions about technology integration in schools are made (Cober et al., 2015, p. 204). A systematic literature review of studies in *Computers and Education*, the highest ranked journal about the pedagogical use of technology, shows that of 352 studies, only 30 percent involved teachers as study participants and only 24 percent involved stakeholders in co-designing technology, whether they were teachers or not (Pérez-Sanagustín et al., 2017, p. A11). A large-scale survey of teachers in Cyprus shows that almost half (43 percent) of 531 teachers experienced having no influence on how technology is introduced in schools (Vrasidas, 2015). Hence, teachers are often seen as implementors, but are denied the opportunity to influence what is being implemented (see Cviko et al., 2014, p. 69 and Kyza and Nicolaidou, 2017, p. 263).

Research objective

A Finnish government report named *The current status of the digitalisation of learning environments in basic education and the readiness of teachers to utilise digital learning environments* calls for involving all stakeholders to make decisions about technology (Tanhua-Piiroinen et al., 2016, p. 65). This dissertation answers this call by examining *participatory design* (PD) as a potential approach for involving teachers as *design partners*. PD is a design and research approach, of which the particular aim is to involve stakeholders directly in the design process (Schuler and Namioka, 1993; Bergvall-Kåreborn and Ståhlbrost, 2008; Simonsen and Robert-

[1] Helsingin sanomat 27.9.2017
[2] Helsingin sanomat 4.10.2017
[3] Helsinging sanomat 18.11.2018

son, 2013). PD is well-known in the field of Human–Computer Interaction, and it has recently gained attention in the education field. For example, in a recent book called *Participatory Design for Learning*, PD was proposed as a suitable approach to improve the development, implementation, and sustainability of learning innovations (DiSalvo et al., 2017, p. 5).

PD has been previously examined in the educational context, most notably when developing technology for children with special needs (e.g. Druin, 2002; Iversen and Dindler, 2013). However, few studies exist in which teachers have been the main stakeholders (also noted by Kyza and Georgiou, 2014, p. 60). Thus, the present research objective is to examine PD in the educational context and from the teacher perspective. This objective is executed with the following research questions:

RQ1: For what purpose have PD studies examined teachers?
RQ2: How are teachers' goals and concerns manifested through PD?
RQ3: What issues can be observed when involving teachers in PD?

The research design comprises three parts. The first question is addressed by conducting a systematic literature mapping of PD studies that have involved teachers. The second question examines teachers' goals and concerns across two projects. The first project, called ONSPACE, involves the development of a learning space system for a new special education school in Finland. The author engaged in the project as a research assistant and later as a software developer. The second project, Technology Comprehension, piloted a new subject for Danish lower secondary education as an elective course. The author engaged in the project during a one-year research visit at Aarhus University. The third question is answered by analysing the issues observed in the two projects and connecting them with the findings from the systematic mapping.

The included publications are presented in Table 1. The semi-automatic literature mapping of PD studies from 2006 to 2016 was published in the *Proceedings of the Participatory Design Conference* (PI). The systematic mapping of the PD studies involving teachers is completed and the draft is submitted to Instructional Science (PII). The findings from the ONSPACE project were presented in the *International Conference of Computer Supported Education* and published in the Springer book series called *Communications in Computer and Information Science* (PIII). The findings from the Technology Comprehension project were published in the *Proceedings of the FabLearn Europe Conference* (PIV) and expanded as a journal article for the special issue of the *International Journal of Child-Computer Interaction* (PV). In addition, the author has published research, not included to this dissertation, about supporting students' interactions with technology in higher education (Tuhkala and Kärkkäinen, 2018) and intelligent learning systems (Gavriushenko, Khriyenko and Tuhkala, 2017).

The contributions of this dissertation are three-fold. First, it contributes to the research in PD: a comprehensive sample of PD studies has been collected and organised into thematic structures with semi-automatic methods (PI) and

TABLE 1 Overview of publications and their relevance to the study.

Research question	**Publication**	**Relation to the research question**
RQ1	PI	Locate thematic structures in PD studies through semi-automatic mapping
	PII	Examine the research purposes of PD studies involving teachers
RQ2	PIII	Summarise the goals and concerns related to the new school and the learning space system
	PIV and PV	Summarise the goals and concerns related to the implementation of the new elective course
RQ3	Dissertation	Analyse issues observed in the two projects and connect them to the systematic mapping

studies that involved teachers identified, categorised, and synthetised (PII). Second, the ONSPACE project contributes to the research on developing technology-enhanced learning environments, and the Technology Comprehension project informs digital fabrication and making in formal education. Furthermore, the projects have practical impact by developing a new system still in use and by reporting the status of educational reform to the Danish Ministry of Education. Third, the dissertation is written in the form of a self-contained publication and contributes to the research on PD in a formal education context. Thus, it does not only summarise the published articles but outlines how to scaffold PD with teachers (Section 5.2).

The dissertation is organised as follows. Chapter 2 introduces PD through four topics: foundations (Section 2.1), user as a design parter (Section 2.2), generating knowledge through design (Section 2.3), and from designing objects to building communities (Section 2.4). Chapter 3 specifies the research design and describes the systematic literature mapping (Section 3.1), design of the learning space system (Section 3.2), piloting of the new elective course (Section 3.3), and methods in this dissertation (Section 3.4). Chapter 4 presents the results, including a synthesis of the mapped PD studies (Section 4.1), a summary of teachers' goals and concerns (Section 4.2), and issues in the two projects (Section 4.3). Chapter 5 presents a discussion of the results (Section 5.1), conclusion (Section 5.2), strengths and limitations (Section 5.3), ethical considerations (Section 5.4), and author's contributions (Section 5.5).

2 PARTICIPATORY DESIGN

There are many design-related research paradigms. Well-known examples, especially in the educational context, include design-based research (Wang and Hannafin, 2005), educational design research (Reeves, 2015), human-centred design or user-centred design (see Iivari and Iivari, 2006; Steen, 2011), and design science (see Cross, 2001). Common to these paradigms is to consider design, practice, and research together: design as envisioning new objects and representing them by drawing, modifying tangible materials, or utilising digital tools; practice as solving concrete problems through iterative cycles of design, development, enactment, and analysis; and research as collecting and analysing data to examine the outcomes.

In this chapter, PD is positioned in relation to the landscape of human-centred design research that has been defined by Sanders and Stappers (2008). A simplified version of this landscape is presented in Figure 1. The horizontal axis has two edges: *user as an informant* and *user as a design partner*. It depicts two different ways to configure user participation in design. In the former, users are investigated – how they perceive and react to different materials, forms, and stimuli – to modify the functionality of the designed object. In the latter, users are active agents who influence and make decisions in design. The edges on the vertical axis are *design driven* and *research driven*. This depicts which outcome is the more predominant purpose of user participation: design objects or construct knowledge. For example, involving users for purely artistic purposes would be design-dominant, and involving users only for data collection purposes would be research-dominant.

Sanders and Stappers (2008) define *User-centred design* as a broad category for approaches in which the user is the object of investigation. In *usability testing*, users test new designs and the objects are modified based on these findings. This can also be based on existing knowledge, such as when designing furniture based on human anatomy, as in *ergonomics*. In *contextual inquiry*, design is informed by interviewing users about use practices, wherein *applied ethnography* the users are observed. As such, all these approaches are research-driven. For example, it is difficult to see how contextual inquiry could be separated from the user inter-

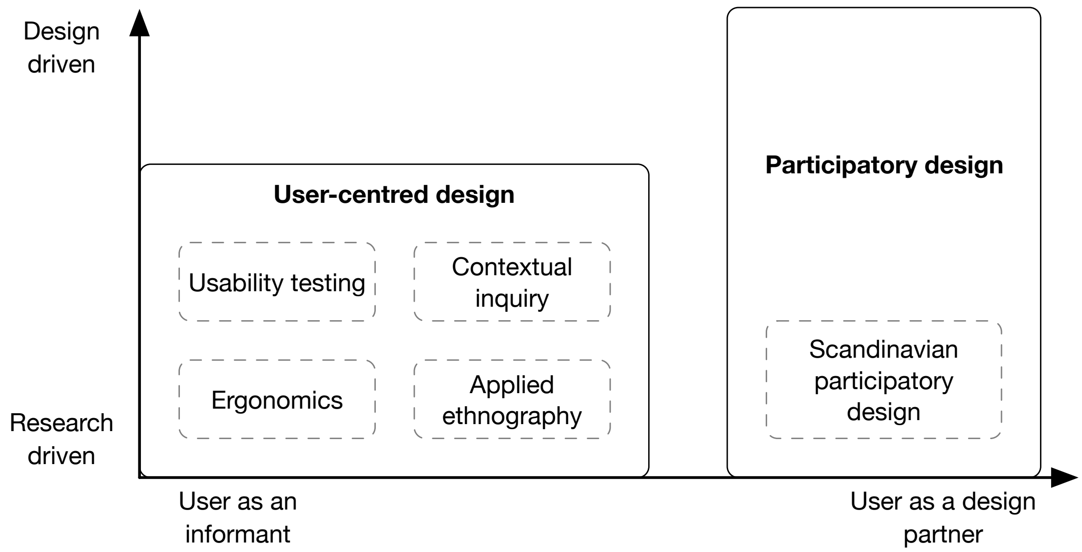

FIGURE 1 Landscape of human-centred design research (adapted from Sanders and Stappers, 2008, p. 6).

views without losing its very purpose.

Similarly, PD can be understood as a broad category. The reason for comparing these two categories is to highlight the differences: while the focus in user-centered design is to investigate users to develop new solutions, the focus in PD is to create a space where users, designers, and researchers explore the problem and envision the solutions together (Leong and Iversen, 2015). This dissertation focuses specifically on *Scandinavian participatory design*. It can be characterised as an action-research inspired approach, which means that both design and research are driven by local accountability: to support the local stakeholders instead of just producing objects and knowledge (see Simonsen and Robertson, 2013, p. 44).

The next sections describe PD within this framework. Section 2.1 provides a brief overview of the PD history, as the topic is thoroughly addressed in *Heritage, having a say* (Kensing and Greenbaum, 2013), *A brief overview of the history of participatory design* (Halskov and Hansen, 2015), *What is participatory design: history* (Spinuzzi, 2005), *Participatory design research overview* (Pilemalm, 2018), and *History* (Bødker and Kyng, 2018). Section 2.2 elaborates on what users as design partners means. Section 2.3 concentrates on the idea of constructing knowledge through design. Section 2.4 presents the recent shift of focus from designing objects to building communities.

2.1 Foundations of participatory design

The roots of PD are in the workplace democracy movement in Scandinavia that emerged in the late 1960s and 1970s. The movement addressed concerns over employees' opportunities to influence how, and with what implications, computer systems were introduced at their workplaces (Beck, 2002). The foundations were built in projects that engaged in this movement, such as the Iron and Metal Workers Union project in Norway, Democratic Control and Planning in Working Life in Sweden, and Democracy, Development, and Electronic Data Processing System in Denmark (see Bjerknes and Bratteteig, 1995; Bødker and Kyng, 2018). These projects demanded more democratic working conditions by increasing workers' influence on the use of technology, developing new technology and work practices, and developing new design methods (Gregory, 2003; Iversen et al., 2012; Bødker and Kyng, 2018).

An important stepping stone for PD was the publication of a book called *Computers and Democracy: a Scandinavian challenge* (Bjerknes et al., 1987). Suchman (1988) described the book as a genuinely human-centered alternative to technology design. This alternative was based on two notions. First, design addresses the contradiction between tradition and transcendence – what is and what could be (Ehn, 1988). Design can either support old practices, values, and power structures or aim to change them. Second, people who are affected by design should be involved in making decisions about it (Greenbaum, 1993; Simonsen and Robertson, 2013). These ideas were disseminated by pioneer researchers like Susanne Bødker (1987) with *Through the Interface: a Human Activity Approach to User Interface Design*, Pelle Ehn (1988) with *Work-Oriented Design of Computer Artifacts*, Joan Greenbaum and Morten Kyng (1991) with *Design at Work: Cooperative Design of Computer Systems*, and Tone Bratteteig (2003) with *Making change: Dealing with relations between design and use*.

Nowadays, PD researchers and practitioners form an established and multidisciplinary community that is more or less committed to the ideals of the Scandinavian tradition (see Vines et al., 2015). Topics like democratic decision-making and empowering marginalised people are still in current debate, especially in the community's main venue: the biannual Participatory Design Conference. At the same time, involving stakeholders has become a mainstream practice in the software industry and the pragmatic side of PD, that is developing techniques for involving stakeholders, has pervaded other design approaches as well (Bødker et al., 2000; Spinuzzi, 2002; Bødker and Kyng, 2018). This has led to an intensive discussion of what are, or should be, the contemporary characteristics of PD (see Halskov and Hansen, 2015; Smith et al., 2017; Bødker and Kyng, 2018; Pilemalm, 2018).

2.2 Involving users as design partners

The notion of a design partner comes from the works of Druin (2002, p. 3), who analysed the ways children take part in design and defined four roles: user, tester, informant, and design partner. Users are the main audience of an existing technology, whose practices are investigated to improve the technology. Testers use technology that is not yet released for commercial use, and the aim is to develop the technology for a larger audience. Informants have an active part throughout the design and provide input before, during, and after the technology is developed. Partners are acknowledged as legitimate decision-makers and promoted with an equal role with designers and researchers. This typology of roles was later expanded with two roles, co-researcher and protagonist (Iversen et al., 2017). Co-researchers take part in gathering and analysing data to investigate the use context side by side with researchers (cf. Duarte et al., 2018), and protagonists develop an ownership to the design project and take the responsibility to pursue it further (cf. Bødker and Kyng, 2018).

This kind of change in participants' role is referred to as *genuine participation* (Bødker et al., 2004, p. 58). In *Routledge International Handbook of Participatory Design*, genuine participation is defined as a *fundamental transcendence of the users' role from being merely informants to being legitimate and acknowledged participants in the design process* (Simonsen and Robertson, 2013, p. 5). Accordingly, this kind of participation actualises when participants are not just answering questions but drawing, sketching, and using other ways to explicate their perspectives. This highlights how PD is about enabling participants to realise that there are alternative choices, to negotiate what they care about most in these choices, and to influence how these choices are pursued (Bødker, 2003; Iversen et al., 2012; Bødker and Kyng, 2018). Establishing genuine participation requires that participants are provided with access to relevant information, an independent position, and a right to take part in decision-making, and that there are appropriate design methods and enough organisational flexibility (Clement and Van den Besselaar, 1993; Kensing and Blomberg, 1998).

However, establishing genuine participation is challenging because there is no single right way to do it (Schuler and Namioka, 1993). Even when the participants are constantly involved in design, they can held back from influencing on any actual decisions (Bratteteig and Wagner, 2012; Frauenberger et al., 2015). For example, this may be the case when the participants are present in design meetings, but lack the proper concepts and language to state their opinions (Bødker, 2003; Simonsen and Robertson, 2013). As a general rule, instead of being satisfied with the fact that the stakeholders are involved, there is a need for cricital reflection: questioning who initiates and directs participation, why certain participants are involved, who these participants are, and who benefits from the outcomes of participation (Vines et al., 2013; Frauenberger et al., 2015; Halskov and Hansen, 2015; Smith et al., 2017; Saad-Sulonen et al., 2018).

2.3 Constructing knowledge through design

It was already introduced in the beginning of the chapter that PD is driven by both design and research. However, there are different ways to understand how these relate. Figure 2 presents four ways in which design and research interrelate: *Design and research separated* represents when industrial design and academic research need to be completely separated from each other. *Research for design* refers to the practice of carrying out research to design better solutions (also known as research-based design). *Design research* refers to research on how to conduct design, such as methods, tools, or principles (cf. science of design in Cross, 2001, p. 53). In *research through design*, design activities have a formative role in generating knowledge (see Zimmerman et al., 2007, 2010).

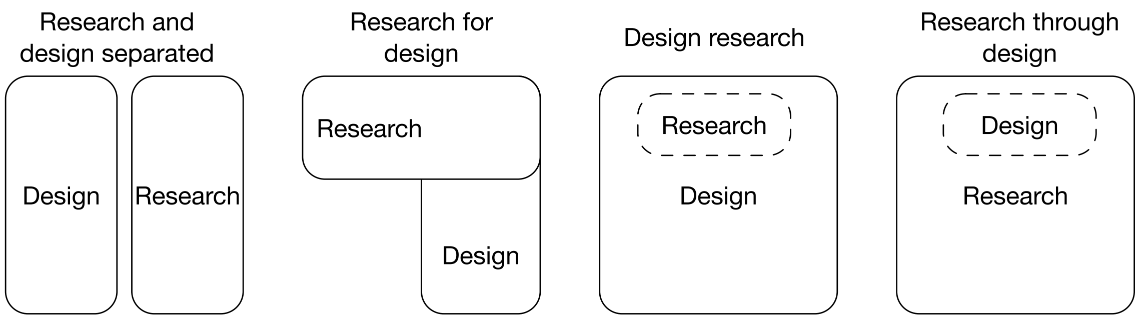

FIGURE 2 Relationships between research and design (adapted from Sanders and Stappers, 2014, p. 27).

PD is considered in relation to research through design. This implies that design activities constitute pre-conditions for generating knowledge (see Frauenberger et al., 2015, p. 98). Practical work establishes a dialogic space, where new knowledge can be constructed through interactions between different stakeholders (Iversen and Dindler, 2013; Bannon et al., 2018). This new knowledge can be about 1) the social context in which the work was carried out, 2) the design outcomes, 3) the methods of conducting and analysing design, and 4) the concepts and frameworks related to design (based on Frauenberger et al., 2015).

Knowledge about the social context comprises, for example, participant conceptualisations of their working and living practices. This knowledge is constructed in a bi-directional process, where the participants reflect their ways of working and designers and researchers aim to understand the context. The goal here is *mutual learning*, which means that while the designers and researchers aim to understand the participants, the participants become aware of their current practices and envision ways to improve them (Kensing and Blomberg, 1998). In this sense, PD relates to etnographical research: understanding participants' practices requires understanding the context, and merely asking is not enough, because what the participants say is not necessarily consistent with what they do (see Pontual-Falcão et al., 2018; Lindtner and Lin, 2017; Grönvall and Kyng, 2013).

The outcomes of design, such as new technologies, concepts, and buildings, often result from creative and uncontrollable activity. Thus, describing the process of producing these outcomes in a scientifically rigorous way can be challenging (Cross, 2001). However, these outcomes are representations of knowledge, into which the decisions and considerations are embedded (Frauenberger et al., 2015). The knowledge these objects manifest is related to the concept of tacit knowledge – people may not be able to articulate their skills with words, but instead by demonstrating them (Spinuzzi, 2005). Similarly, taking the designed objects into use may lead to a better understanding than would reading descriptions of these objects.

Knowledge about methods is constructed by applying, adapting, and developing tools and means to better involve stakeholders. This has been the goal in many PD projects (e.g. Triantafyllakos et al., 2011; Muller, 1991). For example, Andersen et al. (2015) proposed Actor-Network Theory as an analytical tool, Barcellini et al. (2015) developed Actual Role Analysis in Design approach, Malinverni et al. (2016) proposed a multimodal analysis to evaluate participants' actions, and Bratteteig and Wagner (2016) developed a decision-making framework to analyse participation from political perspective. Exploring ways to involve stakeholders is still relevant, as these means are constantly challenged and enhanced due to technological and societal development (Halskov and Hansen, 2015).

Design can also lead to new concepts and frameworks. While these can also be referred to as theories, they are considered more as generative rather than falsifiable (see Gaver, 2012, p. 938). This means that these concepts and frameworks are appraised based on their ability to inspire new insights and raise new issues, instead of being general rules that can be tested. In this sense, these concepts and frameworks focus on describing and explaining certain phenomena instead of predicting. Still, insights regarding practices of design are often referred to as design principles.

2.4 From designing objects to building communities

Identifying and defining participation in a modern technological and societal context is complicated (Bergvall-Kåreborn and Ståhlbrost, 2008; Smith et al., 2017). For example, in open-source software development communities, the boundary between designers and users has become blurred. Because the development work can be distributed all over the world, participation does not necessarily mean physical presence in design activities, but rather influencing from a distance by proposing changes, pointing out problems, and making recommendations. Furthermore, participation is not limited to single-encounter design activities, but develops over time and changes its form (Saad-Sulonen et al., 2018).

To take these new kind of communities into account, *infrastructuring* has become a popular concept (see Bjögvinsson et al., 2012; Dantec and DiSalvo, 2013; Karasti, 2014). It means that the open-source development community, for example, is understood as an infrastructure that connects technical, social, and organisational aspects and includes people, technology, standards, procedures, and practices (Karasti, 2014). Hence, infrastructuring is an action of building these socio-material assemblies (Bjögvinsson et al., 2012). Bødker et al. (2017, p. 269) put this concept into the PD context and defined *participatory infrastructing*. The concept implies that participants are involved in creating the structures, networks, and agreements necessary for sustainable outcomes. The shift from designing objects to building communities brings the focus to 1) how a PD project is configured 2) what happens in the background of PD work, and 3) how the outcomes of PD are sustained (see Iversen and Dindler, 2014; Vines et al., 2015; Bødker and Kyng, 2018; Saad-Sulonen et al., 2018; Smith and Iversen, 2018).

A critical stage of PD is to configure the project. This refers to exploring the project context, anticipating who may be the potential participants, and defining the project's agenda (Vines et al., 2015; Smith and Iversen, 2018). Smith and Iversen (2018, p. 12) conceptualised these actions as *Scoping*, to *define participants in ways that allow for the flexible engagement and agency of diverse stakeholders over time, as well as configuring participation in ways that enable people, practices and networks to (co)evolve*. Thus, the fundamental idea here is to open up the project for potential partners instead of closing it for pre-defined participants.

The second matter is to identify the *back-stage* work behind the *front-stage* activities (see Bødker et al., 2017). Front-stage activities refer to workshops, design sessions, and other arrangements typically reported in research papers. However, most of the actual decisions are made back-stage, such as when the project goals are negotiated, outcomes evaluated, and conclusions derived (Frauenberger et al., 2015). Opening up the back-stage to an external audience increases transparency as to how the project unfolds and how the participants influenced decisions (cf. Frauenberger et al., 2015).

Third, when the PD project is over, the challenge is to sustain the outcomes of the PD project. It is critical that the project has developed resources for its stakeholders by this point, so that they may take ownership and responsibility for continuing the project (Iversen and Dindler, 2014; Bødker and Kyng, 2018). Iversen and Dindler (2014) define the forms of sustainability as: *maintaining*, *scaling*, *replicating*, and *evolving*. Maintaining refers to integrating the outcomes of a PD project into existing practices, so that the initiative itself does not stop even though the project ends. Scaling refers to the effort of expanding outcomes into larger contexts and communities without losing the essence of the initiative's agenda. Smith and Iversen (2018, p. 20) describe this further as establishing networks of people and organisations, knowledge frameworks, and visions for developing and implementing long-term strategies. The idea of replicating is somewhat similar, but with the aim of transferring the initiative to other contexts instead of expanding. Finally, evolving means that the developed ideas in the project can change and that abstract ideas may actualise into concrete outcomes later on.

3 RESEARCH DESIGN

A timeline of the dissertation work is presented in Table 2. As can be noted, the research design consists of three parts: a systematic literature mapping and two projects. Section 3.1 describes how the articles for the systematic literature mapping were collected. The reason for this part was to establish a strong theoretical background: PD is a multi-disciplinary field so research is often published in discipline-specific journals and conferences and locating relevant body of knowledge can be challenging. The mapping examined ten years of PD studies involving teachers, and the findings served as a basis for analysing the two other parts.

TABLE 2 Timeline of the dissertation work.

Dates	Dissertation stage
8/2014 – 12/2014	Research assistant in ONSPACE project
1/2015 – 12/2015	Software developer in ONSPACE project
01/2016 – 5/2017	Systematic literature mapping
8/2017 – 5/2018	Researcher in Technology Comprehension project
6/2018 – 6/2019	Final analysis and finishing dissertation

The two other parts are the research projects that the author was involved during the dissertation work. The first project is called ONSPACE, which involved teachers to design the learning space system, and the second one is called Technology Comprehension. Sections 3.2 and 3.3 summarise how these projects unfolded, what research activities were carried out, and what data was collected. Section 3.4 describes how the findings in this dissertation were constructed.

3.1 Systematic literature mapping

Data collection took place over 14 search engines and databases to gather a wide sample of PD literature: ACM Digital library, Bielefeld Academic Search Engine, EBSCOhost Research Databases, ERIC Institute of Education Sciences search, IEEE

Xplore Digital library, JSTOR, ProQuest, SAGE Journals, ScienceDirect, Scopus, SpringerLink, Taylor and Francis Online, Wiley Online Library, and Thomson Reuters Web of Science. Criteria for database selection were the possibility to 1) export multiple references and 2) export references in Mendeley supported format (RIS, Bibtex, Endnote XML, or Zotero). Thus, Google Scholar, Semantic Scholar, and CiteSeerX were excluded.

References where *participatory design* appeared in title, abstract, or keywords, and which were published between 2006 and 2016 were collected. The references from different search engines were imported to the Mendeley reference management tool to build a single reference database (2943 articles). Because two references could have different meta-information and still point to the same source, the duplicates were removed by using the duplicate identification tool.

The article database was exported to a Python preprocessor (developed in Nieminen et al., 2013). The preprocessor created a word matrix, which was used in the semi-automatic clustering of the articles. After the clusters were produced, the findings were illustrated as a cluster map. To validate the mapping results, six education-related clusters were identified and the word portions analysed. The findings and the clustering procedure are described more in detail in PI.

This work continued in PII. The reference database was updated by repeating the data collection procedure for the year 2017, and the references from 2006 were removed. From the reference database, the references that included the word *teacher* either in title, abstract, or keywords were extracted. In total, 191 references included both *teacher* and *participatory design*.

The data refinement process is illustrated in Figure 3. In the first exclusion stage, the references were screened and those not published in a journal or conference, written in English, or where there was no access to full text in any of the 14 databases were removed (55 articles). The excluded references consisted of workshop desriptions, research proposals, posters, extended abstracts, introductions to special issues, and editorial notes.

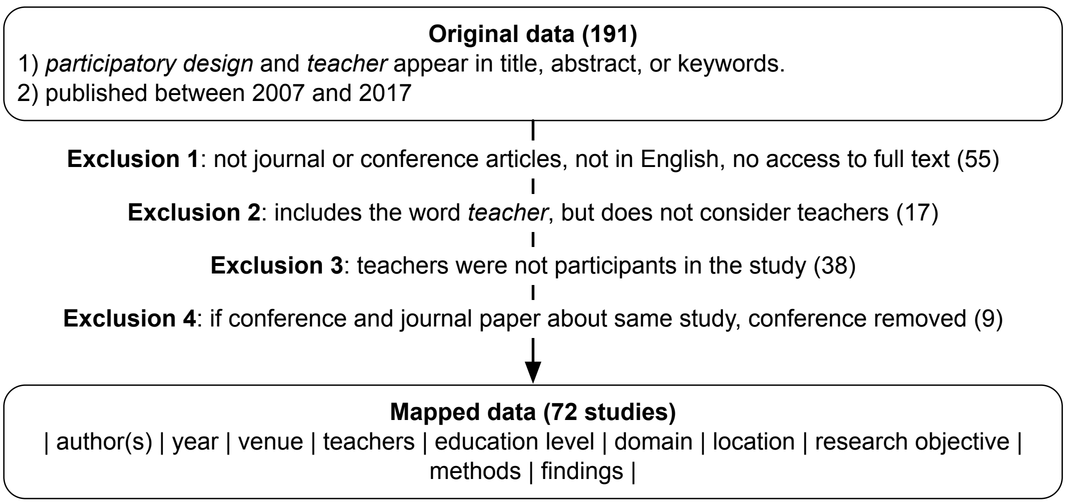

FIGURE 3 Systematic literature mapping protocol.

Before the second exclusion stage, full text articles for each remaining reference were downloaded. Articles that included the words *participatory design* but defined the study as action research, user-centred design, or another research approach were eliminated for being beyond the scope of the present study (17 articles).

In the third exclusion stage, the articles that did not involve teachers as participants were removed (37 articles). For example, Hussain (2010) stated that *valuable user perspectives are lost if only information from adult carers such as **teachers** and parents are included in the design process* but did not consider teachers any further. Studies that did not define the participants in detail, but obviously considered teachers, were included. The final exclusion stage (9 articles) removed conference articles where the same research was reported in a journal article (cf. Fage et al., 2014 and Fage et al., 2016). As a result, there were 72 PD studies that had involved teachers.

3.2 Designing learning space system for open and adaptable school

Valteri School Onerva is part of the national Valteri Centre for Learning and Consulting Centre in Finland. The school provides pre-primary, basic, and voluntary additional basic education and is specialised in meeting student needs related to vision, hearing, language, and interaction [1]. The school constructed a new building, which was put into use in 2016.

A draft of the new school building is seen in Figure 4. The theoretical idea for the building was based on Marko Kuuskorpi's dissertation (Kuuskorpi, 2012), and the school concept was designed by Julianna Nevari (Nevari, 2013). The concept is illustrated in Figure 5. The learning areas comprise of parks, fountains, and dens. A park is an open space, which can be easily modified for group work, presentations, and physical activities. A fountain is a partially open space for collaborative learning, which can be divided into different areas. A den is a quiet, individual, and closed space that is used for focusing on tasks.

The purpose of the new school building is to encourage teachers to utilise new spaces for pedagogical activities. This means that learning activities happen in the space most suitable for current needs, instead of gathering learning resources into the classroom. The practical problem of the school was to figure out how the teachers would organise their activities without information on which spaces are available.

Design stage

The ONSPACE project was initiated on May 1 2014 to address how the teachers could organise their activities by using modern technology. The project was carried out collaboratively between the Faculty of Information Technology (the University of Jyväskylä) and the Valteri School Onerva. The participants included a

[1] Official website of the Valteri School Onerva

FIGURE 4 A draft of the Valteri School Onerva building from the construction project brochure.

FIGURE 5 The school concept (Nevari, 2013).

researcher team, special education teachers, occupational therapists, visual sense specialists, and technical staff. The participants expressed that they were not content with the outdated facility management system of the previous school. To develop a system that would better meet the teachers' needs, the purpose of the design stage was to elicit the features of a learning spaces system.

The design stage lasted until December 15 2014, and the main activities are presented in Table 3. All activities were carried out in the old school's facilities to give participants familiar surroundings and to give researchers a better understanding of the context. The meetings focused on eliciting needs regarding the new school and envisioning ways to meet those needs.

TABLE 3 Design stage activities in the ONSPACE project.

Date	Participants	Activity	Materials
14.5.2014	8 teachers, 1 technical staff, 3 researchers	Group discussions, examining a 3D-model of the building	Recorded discussions, conceptual map of the building
24.8.2014	6 teachers, 4 researchers	Eliciting participants' needs about the building	Recorded meeting, list of needs and hopes
27.9.2014	6 teachers, 3 researchers	Presenting and discussing initial use cases and requirements	Recorded meeting, use cases, initial requirements
10.11.2014	Technical administrator, 1 researcher	Semi-structured interview	Recorded interview, technological specification
12.12.2014	6 teachers, 2 instructors, 3 researchers	Group evaluation of the design stage outcomes	Recorded evaluation, requirements specifications

Development stage

The outcomes of the design stage served as a basis for developing the system. The sequel project, ONSPACE2, was scheduled to run between May 1 and December 31, 2015. Most of the participants had also served in the design stage. During the development stage, monthly design meetings were held to report on the development work and allow participants to give their feedback and recommendations on how to proceed (Table 4). The aim was to enable the participants to influence how their expectations were transformed into a working system.

The new school building opened in January 2016, and the ownership of the learning space system (source code, documentation, intelligent property rights) was transferred to the Valteri School Onerva. However, the system still lacked two critical requirements: the option to make recurring reservations and the ability to log into the system using existing user accounts. To implement the missing features, the school recruited a freelance software developer in March 2016. The system was put into use in late Spring 2016 [2].

3.3 Piloting Technology Comprehension as an elective course

As a part of educational reform in Denmark, the Ministry of Education initiated a new subject for Danish lower secondary education (13–15 y.o. students). The subject, *Technology Comprehension* consisted of three learning objectives: to develop basic skills in computing, such as programming, algorithms, pattern recognition,

[2] ONSPACE web interface, accessed 15.3.2019

TABLE 4 Development stage activities in the ONSPACE project.

Date	Participants	Activity	Materials
17.6.2015	Principal investigator and head of the school	Project initiation: timetables, goals, and contracts	Official project documents
27.8.2015	8 teachers and 3 researchers (including 2 developers)	User interface design	User interface sketch, session recording
21.10.2015	8 teachers and 3 researchers (including 2 developers)	Development meeting, review of the development status	Meeting recording
19.11.2015	Same as previous	Same as previous	Same as previous
17.12.2015	Same as previous but including technical staff	Final meeting where the ownership of the system was transferred	Meeting recording, system documentation

and abstraction; skills to specify and articulate a problem and utilise an iterative design process to develop a digital solution; and skills to reflect and evaluate the digital solution, its applicability, impact, and ethical concerns with reference to the broader socio-political context within which it is applied.

To support the implementation of Technology Comprehension across 13 schools, the ministry commissioned a research project with the Centre for Computational Thinking and Design in Aarhus University. The head of the centre (one of the dissertation supervisors) invited the author of the present dissertation to join the project as a visiting researcher. The project goals aligned with the present research objective, as the research in the centre was grounded in Scandinavian participatory design (see Smith et al., 2015, p. 22).

The project activities are summarised in Table 5. The research started by sending an electronic survey to the participating schools. The survey asked about each teacher's professional background, anticipated challenges regarding Technology Comprehension, and outlined expectations of being part of the project. During winter 2017, the project involved school visits and semi-structured interviews with 14 teachers. The interviews examined the expectations of those not yet teaching the course, and the experiences of those already conducting Technology Comprehension classes. Technology Comprehension lessons were observed during these visits if the schools allowed.

A one-day workshop was held to develop support for the teachers of the course. The workshop was held once in Aarhus and once in Copenhagen. The workshop programme allowed the teachers to get to know one another, examine the Technology Comprehension learning goals, introduce computational thinking and design, and program with Micro:bits. The workshop also included theme discussions about the following topics: what is Technology Comprehension as an elective course for you; how do you incorporate Technology Comprehension in your current teaching; how do you perceive the competency goals; and what

TABLE 5 Activities in the Technology Comprehension project.

Date	Participants	Activity	Materials
Autumn 2017	Principal investigator, ministry	Project initiation	Learning objectives, curriculum documents
15.10.2017	13 schools	Electronic survey	Survey answers
1.11.2017 – 31.1.2018	14 teachers, researchers	School visits	14 recorded interviews, field notes
19.2.2018	8 teachers, 1 pedagogical consultant, 3 researchers	Workshop in Aarhus	Workshop recording, self-assessment, feedback, theme discussion
21.22018	7 teachers, 2 principals, 3 researchers	Workshop in Copenhagen	Same as in Aarhus
25.4.2018	Teachers and educational professionals	FablearnDK conference in Kolding	Posters, field notes

should Technology Comprehension be in future.

At the beginning of the workshop, the teachers filled a self-assessment questionnaire. The questionnaire included Likert-scale questions about perceived competencies in using digital tools and in teaching design and computing topics, as well as open questions about learning methods, positive or negative experiences, and the skills needed to teach Technology Comprehension. The teachers were tasked to utilise the workshop ideas in their teaching and produce a poster about these activities with students. At the end of the workshop, the teachers filled a feedback questionnaire. The developed posters were published in the FablearnDK conference in Kolding [3].

3.4 Summary of methods in this dissertation

Previous sections described what data was collected during the dissertation work. Table 6 presents data and the analysis methods that were used to construct the findings of this dissertation. Most of data was already pre-processed for the purposes of the individual publications: the design meeting recordings were transcribed and survey answers in Danish translated to English. It needs to be noted that, however, the analysis process was not straightforward, but rather continous interaction between literature mapping findings and insights from the projects.

The analysis of the articles was carried out by the author and consisted of three stages. First, the articles were screened through to gather basic information. From each article, the following information was extracted to an Excel sheet: author(s), year, venue, participants, number of teachers as participants, other stakeholders, education level, and geographical location. In the second stage, the ar-

[3] FabLearnDK 2018 website, accessed 20.12.2018

TABLE 6 Summary of methods in this dissertation

Research question	Data	Analysis
RQ1	72 PD studies that have involved teachers	Organise the studies into categories according to the research purpose
RQ2	ONSPACE: eight recorded design meetings	Research question based coding of design meetings
	Technology Comprehension: survey answers, interview and field notes, workshop recordings	Theme-building based on research questions
RQ3	ONSPACE: eight recorded design meetings, interview with technical staff, project documentation, development documents	Identify issues within the project and connect them to the RQ1 findings
	Technology Comprehension: survey answers, interview and field notes, workshop recordings	Identify issues within the project and connect them to the RQ1 findings

ticles were scrutinised more in detail to identify research objectives, methods, and main findings for each article. The Excel sheet was examined to define high level categories for the articles. The categories that emerged were environments, practices, and technologies. After the studies were organised into these three categories, they were further refined into sub-categories. A synthesis of the mapped studies was written based on the developed categories.

The author exported the design meeting transcriptions into Atlas.TI to examine the teachers' goals and concerns within the ONSPACE project. Utterances that referred to something that the teachers found valuable, or worrying, were marked as quotations and assigned with a code *goal* or *concern*. The quotations were further assigned with a code that referred to the object of goal or concern. The codes were scrutinised to develop answers for the research question. When regarding the Technology Comprehension project, examining the goals and concerns had been already done within the project (see PV). Data had been analysed with the other project researchers by watching the recorded theme discussion together, negotiating potential themes, and riching the themes with survey answers.

For the third question, all materials from the two projects were examined by the author. The aim was to identify what issues the projects had. However, it needs to be emphasised that the identified issues represent the author's perspective, as discussed in Section 5.3. Furthermore, the fact that the author had been acquainted with PD literature clearly had effect on how the projects were reflected. After the issues were recapitulated, the findings for the RQ1 were examined again. The purpose was to examine how the identified issues have been addressed in previous PD literature that has involved teachers.

4 RESULTS

Section 4.1 presents the categories produced through the systematic literature mapping and overviews the studies within these categories. Section 4.2 describes the teachers' goals and concerns regarding the open and adaptable school in the ONSPACE project and the new curriculum in the Technology Comprehension project. Section 4.3 presents the issues regarding identifying roles, needs, rights, and responsibilities, positioning participation as a possibility instead of an obligation, and clarifying an agenda for sustainable outcomes.

4.1 Environments, practices, and technologies

A summary of the studies involving teachers in PD is presented in Table 7. Most of the studies were published in journals (51). The studies considered several education levels: pre-primary, primary, secondary, and higher education. Moreover, seven studies were about PD in teacher education, and six investigated PD in more than one education level. Most of the studies were small-scale investigations such as case studies, with no more than five teacher participants. Seven large-scale studies consulted 20 or more teachers. However, some studies did not specify the exact number of teacher participants. Over half the studies were conducted in the United Kingdom, Netherlands, United States, Australia, and Finland, and five studies covered more than one geographical location.

Environments

Table 8 presents the studies related to learning environments. In the largest category, *School buildings*, teachers were involved in envisioning a new school concept or re-design of an existing concept (Burke and Könings, 2016; Koutamanis et al., 2017; Könings et al., 2017; van Merriënboer et al., 2017; Woolner et al., 2007, 2010). These studies approached the school building as a whole, including furniture, (technological) equipment, materials, and structures, whereas two of the studies

TABLE 7 Summary of participatory design studies involving teachers ($n = 72$).

Venue	Education level	Number of teachers	Location
Journal: 51 Conference: 21	Pre-primary: 2 Primary: 22 Secondary: 19 Higher: 16 Teacher education: 7 Several levels: 6	Not defined: 22 1 – 5: 25 6 – 10: 9 11 – 20: 9 Over 20: 7	United Kingdom: 16 Netherlands: 10 United States: 7 Australia: 5 Finland: 4 Rest of Europe: 16 Asia: 6 Rest of the world: 3 Multiple locations: 5

focused on specific facilities: the university cafeteria (Lundström et al., 2016), and library learning commons (Somerville and Collins, 2008). In the second category, *Technology-enhanced learning spaces*, the studies focused not only on the physical space but also on how technology is integrated into the learning environment.

TABLE 8 Teachers in participatory design of environments ($n = 15$).

Category	Articles
School buildings	Burke and Könings (2016), Koutamanis et al. (2017), Könings et al. (2017), Lundström et al. (2016), van Merriënboer et al. (2017), Somerville and Collins (2008), Woolner et al. (2007), Woolner et al. (2010)
Technology-enhanced learning spaces	Bossen et al. (2010), Casanova and Mitchell (2017), Cober et al. (2015), Joyce et al. (2014), Kreitmayer et al. (2013), Otero et al. (2013), Stephen et al. (2014)

Regarding the studies in the *School buildings* category, Burke and Könings (2016) examined how a school's history inspired the participants' design imagination. They present an example from the Netherlands, De Werkplaats, a school that was re-designed according to the educational thinking of Kees Boeke. They point out how a historical narrative can be utilised as a positive agent for change, but also that previous traditions from more conservative schools can limit and hinder the potential for design innovations.

Two other studies took place at De Werkplaats. As reported by Koutamanis et al. (2017), visual information technology (Building Information Model) was utilised as a collaborative tool during the building's lifecycle. The tool served as a knowledge repository and a communication service, which enabled the participants to engage in decision-making. van Merriënboer et al. (2017), in turn, addressed the relationship between pedagogy and physical spaces. They framed a three-stage design process: specifying the pedagogy, aligning the chosen pedagogy with seating arrangements and physical learning spaces, and realising the school building. They found PD especially beneficial when teachers' pedagogical needs and architects' non-pedagogical needs (resources, cost-effectiveness) contradicted (also in Woolner et al., 2007). van Merriënboer et al. (2017) conclude that the PD of school buildings is not about the building *per se*, but negotiating a shared pedagogical vision and establishing a commitment to this vision.

Two methodological contributions deserve to be highlighted. Woolner et al. (2010) accounted for using visual tools, such as photo elicitation, diamond mapping, and map-based activities, to gather perceptions of various participants and to improve the learning environment. They concluded that the visual methods produced rich understandings of the current school environment and enabled the triangulation of participants' different perceptions. The second study developed an interdisciplinary model of practice for participatory building design (Könings et al., 2017). The model integrates an action research cycle, stakeholder analysis model, ladder of participation tool, and participation matrix to address the complexity of involving several different stakeholder roles.

In the *Technology-enhanced learning spaces* category, three studies developed technologies to be integrated into classrooms: an Internet of Things ecosystem (Joyce et al., 2014), UniPad application (Kreitmayer et al., 2013), and digital displays (Otero et al., 2013). Two studies involved teachers in designing new learning environments where technology plays a major part. Casanova and Mitchell (2017) provided participants with two provocative design space concepts, which were then re-designed. This process resulted in rich data about how the participants conceptualised the learning spaces and the value of technology. Similarly, Stephen et al. (2014) involved teachers and students to design technology-rich classrooms as *community spaces* that are owned and maintained together.

Two studies are described in detail because they pay specific attention to teachers' participation. Bossen et al. (2010) accounted for a large PD project, *iSchool*, which was about envisioning new learning spaces and opportunities of pervasive technology. They interviewed the teachers three years after the project ended and examined what they gained from the project. According to the teachers, the most satisfying experiences were: reflecting with professionals from other backgrounds, the enthusiasm of the students towards technology, and gaining experience from using modern technology. Moreover, the teachers expressed four types of gains: opportunity to reflect on teaching methods, to develop skills and understandings about technology, to have leverage to influence technology-related decisions, and to advance their own interest in technology.

Cober et al. (2015) analysed teacher engagement in two case studies and investigated what supports teacher participation. The teachers engaged in: theory-driven discussions with researchers and developers to ground design work and understand each others' perspectives; design partnerships by providing input, guidance, and ideas; reflecting on the innovations from a pedagogical perspective and evaluating the potential impact for students; and adjusting implementation enactments. Regarding the conditions supporting the teachers, the authors highlighted a combination of highly facilitated conditions and flexibility, an atmosphere of trust and partnership, and designing with contextual knowledge about the physical environment, students, and potential technologies.

Practices

The studies in the *Learning practices* category were about establishing professional communities, intstructional design, and professional development programmes (Table 9).

TABLE 9 Teachers in participatory design of practices ($n = 29$).

Category	Articles
Communities	Booker and Goldman (2016), Duell et al. (2014), Farooq et al. (2007), Ishimaru and Takahashi (2017), Karimi et al. (2017), Pollock and Amaechi (2013), Selwyn et al. (2017), Tammets et al. (2011), Vakil et al. (2016)
Instructional design	Anderson and Östlund (2017), Barbera et al. (2017), Gros and López (2016), Harrison et al. (2017), Janssen et al. (2017), Kuure et al. (2016), Könings et al. (2011), Könings et al. (2010), Könings et al. (2007, A), Könings et al. (2007, B), Prins et al. (2016)
Professional development	Al-Eraky et al. (2015), Goeze et al. (2014), Janssen et al. (2014), Kyza and Georgiou (2014), Kyza and Nicolaidou (2017), Põldoja et al. (2014), Rodrigo and Ramírez (2017), So et al. (2009), Tulinius et al. (2012)

In the *Professional communities* category, two studies examined online communities. Duell et al. (2014) established a yearly ambassador programme for introducing design thinking as a general competency in K-12 education in Australia. In this study, PD was undertaken to create an online design education platform and to increase teachers' capacity to teach creativity and design. Farooq et al. (2007) developed an online environment for a diverse community of distributed education professionals. The project drew on PD and included four design interventions. The study proposed that the interventions were successful because the community members developed ownership over the online environment and kept using it for long-term professional development and social networking. Karimi et al. (2017) organised a *hackathon* workshop for teachers, where the teachers experimented with technology and designed learning activities. Because the teachers faced challenges implementing the digital technology projects, it provided an honest experience of exploring novel technologies and demystifying some aspects of technical practices.

The other studies in this sub-category were about empowering local communities. Booker and Goldman (2016) examined PD as an approach to tackle math fears in families by restoring epistemic authority. Pollock and Amaechi (2013) explored how texting supports rapid and individualised communication with vulnerable youth. Selwyn et al. (2017) explored the possibilities of making existing school data available in digital form for teachers, students, and administrators. This study revealed technical, informational, organisational, and social issues in democratising data engagement within school settings. Tammets et al. (2011) examined a teacher accrediation programme that requires the teachers to be involved in community of practices, collaborative learning, and knowledge building. Finally, Vakil et al. (2016) used the notion of politiced trust to analyse how political and racial solidarity was established, contested, and negotiated throughout two PD projects.

The *Instructional design* category consists of studies about designing learning practices and curricula. Most of the studies were conducted by the same researchers from the Netherlands. Könings et al. (2007, A) aimed to reduce discrepancies between students' and teachers' perceptions on appropriate learning environments and to collaboratively design these environments. Könings et al. (in 2007, B) expanded this work by focusing on teachers. In two other studies (Könings et al., 2010, 2011), the authors invited students to collaborate with teachers. Both the teachers and students found PD appealing in this context, but with several challenges: PD takes too much time, students underestimate their capability to decide educational issues, teachers doubt students' willingness to take part in PD, and PD outcomes were perceived positively by the students involved but not by the rest of the class.

Janssen et al. (2017) defined *participatory educational design* and conducted a study with three aims: to view classroom teaching as bounded rational design, develop a tool that supports participants in mapping and sharing their goals, and develop another tool that helps participants to explore practical and effective possibilities for designing learning environments. This study demonstrated the use of tools for improving the quality and usability of learning environments and stated that even participants with similar backgrounds benefitted from learning about each others' practices and goals.

The remaining studies in this sub-category considered a variety of topics. Barbera et al. (2017) developed learning scenarios to identify *moments of change* and describe causes and agents that motivate these changes. Gros and López (2016) examined the Learning Centric Ecology of Resources model to facilitate co-design processes. Two studies considered assessment in teaching: Harrison et al. (2017) explored how to redesign a summative assessment culture that takes into account students' post-assessment feedback, and Anderson and Östlund (2017) considered assessment practices of students who attend special schools. Janssen et al. (2014) developed a PD-based teacher training trajectory for guided discovery learning (GDL) lessons in biology. Accordingly, the teachers were willing and capable of implementing GDL, utilised the heuristics that were developed by experienced teachers, and valued GDL at a higher level than regular lessons. Kuure et al. (2016) supported English teachers in a Finnish university to become designers of language learning with new technologies, and Prins et al. (2016) developed an instructional framework that provided educational designers with a set of prescriptive guidelines for transforming authentic modeling practices.

Two studies in the *Professional development* category were about improving professional development through PD. Kyza and Georgiou (2014) examined PD for promoting teachers' sense of ownership towards inquiry-based learning modules. Accordingly, the teachers perceived PD as a collaborative and supportive framework that enables the exchange of different perspectives, encourages critical constructivism, and facilitates new teaching methods and technologies. Conversely, the time-consuming nature of PD, communication problems, and participants' unequal contributions were identified as the main disadvantages. Despite this, all teachers preferred designing the teaching module over using pre-made modules. Kyza and Nicolaidou (2017) conclude that iterative design facilitated teachers' professional development because it enabled teachers to reflect on inquiry learning and teaching.

The remaining studies in this category were about training programmes. Al-Eraky et al. (2015) involved teachers in designing a faculty development programme for teaching professionalism in medical education, Rodrigo and Ramírez (2017) developed a master course for online teaching, and Tulinius et al. (2012) designed a programme for teachers to obtain critical appraisal skills and higher academic capacity. Four studies were about developing digital platforms for professional development: Goeze et al. (2014) examined how video case-based learning could promote teachers' analytical competence to become immersed and to adopt multiple perspectives, to apply conceptual knowledge, and to describe pedagogical situations. Similarly, Põldoja et al. (2014) addressed the design challenges of a software solution for self- and peer-assessing teachers' digital competencies. Finally, So et al. (2009) designed an online platform where teachers can share vivid images of their practices with their peers.

Technologies

The studies regarding learning technologies were assigned to the following categories: *Assessment and monitoring tools*, *Educational games*, *Learning and teaching applications*, *safety and security tools*, and *Technology for special needs* (Table 10).

TABLE 10 Teachers in participatory design of technologies ($n = 28$).

Category	Articles
Assessment and monitoring tools	Gillies et al. (2015), Rodríguez-Triana et al. (2012), Siozos et al. (2009)
Educational games	Hoda et al. (2014), Klonari and Gousiou (2014)
Learning and teaching applications	Carmichael (2015), Cramer and Hayes (2013), Girard and Johnson (2010), Hannon et al. (2012), Kalra et al. (2007), Pedersen et al. (2012), Rahamat et al. (2011), Song and Oh (2016), Su et al. (2010), Triantafyllou and Timcenko (2013)
Safety and security	Ervasti et al. (2016), Jutila et al. (2015), Pantsar-Syväniemi et al. (2015)
Technology for special needs	Abdullah and Brereton (2015), Bossavit and Parsons (2016), Brereton et al. (2015), Medeiros-Braz et al. (2017), Fage et al. (2016), Herstad and Holone (2012), Lingnau and Lenschow (2010), Parsons et al. (2011), Parsons and Cobb (2014), Zainuddin et al. (2010)

In the *Assessment and monitoring tools* category, Gillies et al. (2015) developed an application for giving feedback about students' playing posture in music education. They created a prototype, then asked teachers for feedback before developing next version for evaluation. Rodrigo and Ramírez (2017) developed computer-supported collaborative learning scenarios for monitoring students' interactions. Siozos et al. (2009) reported positive outcomes after involving teachers and students in designing computer-based assessment tools: both teachers and students perceived PD as an opportunity to re-conceptualise existing pedagogies and that PD supported locality, diversity, participation, and attitudes that counter impassivity and homogenisation.

Two of the studies were about *Educational games*. Hoda et al. (2014) involved teachers as part of a multidisciplinary team that designed a game for supporting reciprocal teaching and collaboration with children. They evaluated and refined the game through functional testing, teacher trials, and children–teacher trials. As an outcome, the game was perceived as engaging and easily understood by young children. Klonari and Gousiou (2014) described a game for helping teachers to become aware of their pedagogical choices. The game itself was described in detail, but it remained unclear how the teachers engaged in the design of the game.

The studies in the *Learning and teaching applications* category designed technology for dance and environmental education (Carmichael, 2015), financial education (Cramer and Hayes, 2013), STEM education (Hannon et al., 2012; Su et al., 2010), mathematics (Pedersen et al., 2012; Triantafyllou and Timcenko, 2013), and literature (Rahamat et al., 2011). Three studies examined the development of tutoring systems (Girard and Johnson, 2010; Kalra et al., 2007; Song and Oh, 2016). The studies in this sub-category focused on the technologies themselves. An exception was the study by Carmichael (2015), which criticised the assumptions behind education technology development. That is, it concerned the risks of designing educational technology based on stereotypical views, such as *digital natives*, and losing sight of practice-based knowledge.

All three studies in the *Safety and security* category related to designing a situation-aware safety service. Jutila et al. (2015) examined the technological enablers and requirements for building a safety system, Pantsar-Syväniemi et al. (2015) analysed the design process itself, and Ervasti et al. (2016) analysed the feedback from children, parents, and teachers. Even though the design clearly focused on children, these studies were able to bring together various perspectives from teachers and parents as well.

The largest category was *Technology for special needs*. The studies considered various special needs, such as Autism Disorder, language delays, and cognitive and sensory impairments. Some studies focused on identifying requirements for technology design (Lingnau and Lenschow, 2010; Zainuddin et al., 2010) or describing how technology can support these needs (Abdullah and Brereton, 2015; Fage et al., 2016; Herstad and Holone, 2012; Parsons et al., 2011). Medeiros-Braz et al. (2017) emphasised that teachers have valuable knowledge about students' special needs and can envision technologies to support students' abilities and learning possibilities. In contrast, Brereton et al. (2015) noted that teachers (and other adults) have their own needs, and these can be different than the actual objectives of the students who have special needs.

Finally, two methodological contributions stand out in this category. Bossavit and Parsons (2016) utilised a stakeholder analysis framework to reflect the design process of an educational game. The framework was grounded in PD literature and used to map stakeholder roles, levels of engagement, design tools, and decisions. Parsons and Cobb (2014) addressed the complexity of involving multiple stakeholders: in this case, teachers and children with special needs. They discussed how the key challenge is to prioritise different stakeholders and decisions. They argue that prioritising each stakeholder equally is impossible and question if an outcome-focused agenda, which aims for efficient technology development, is even possible to combine with the empowering approach of PD.

4.2 Teachers' goals and concerns

This section summarises the goals and concerns of the teachers involved in the two projects.

The open and adaptable school

The main goal of the teachers from Valteri School Onerva was to harness a new perspective on learning spaces: *In the previous school, we are used to certain conventions. They are like unwritten rules that certain spaces are only for certain people and for certain use. We want to renew the whole culture of using learning spaces.* This goal was further exemplified by a teacher: *Crafting spaces are normally only meant for crafting lessons. However, these spaces are often free, and they could be used for teaching some mathematical concepts, such as measuring. But how do you communicate these kind of needs and possibilities during the hectic days?*

This new perspective was related to creative use of space, especially in the context of supporting action-based learning activities. The teachers pointed out that their student groups are smaller than class sizes in basic education, which makes it easier for the group to move between spaces. In this sense, the teachers emphasised that they want to get away from the desks and start moving: *What could be more natural way of learning than going to an environment where you can learn something by actually doing it?* However, the differing levels of students' perceptional abilities were noted as a challenge to creative use of spaces because blind students, for example, need to be able to navigate in the building without assistance.

The open school represented not only open physical spaces, but also the opening up of the work practices for increased collaboration. In the previous school, when a certain space was reserved for a certain group, it was difficult for other groups to ask if they could join and use the same space. The teachers noted that they hoped the new school to inspire them to find better ways to communicate and initiate collaboration: *Hopefully it could enhance collaboration if we are able to show that others are welcome to the space we have reserved.*

One concern that the teachers expressed was related to privacy and security in the new school. They emphasised that even in the open school, it is necessary to have spaces for private conversations. This includes both audible and visual privacy, because communicating in sign language is a normal occurrence: *Despite the fact that there are open spaces, there needs to be spaces for private communication. We have lots of confidential conversations with parents and other stakeholders. In the current school, if the phone rings and students are present, we may use cleaning closet – or whatever place – to talk.* From the perspective of security, the teachers pointed out what kind of practical problems working in special education has: *Many of my students are almost or completely deaf. If I give them a task, where they can choose the place where they work, how am I suppose to reach them in this open school environment.* Even though there are communication devices, organinsing a group of students is more complicated in the large school than in a single classroom.

The teachers outlined their another main concern with the new school as follows: *When we are acting during a normal hectic day, how are we supposed to know what spaces are free when we need them? This is the main problem we try to resolve with technology.* Without permanent classrooms and learning activities scheduled around the school, preventing work from becoming chaotic becomes a difficult task. Thus, the teachers hoped for: *A system that would be available in the new school, so that it makes possible to get up and go actually doing something.* Still, the teachers stressed that they are committed to the idea of open and adaptable school, and that the system must not become a barrier for this vision: *The system needs to be fast and easy, otherwise we will not use it. We want to concentrate on our work, not on managing learning spaces. Where [pedagogical activity] happens, should be a matter of pedagogical choices, not technological.* This demonstrates that the teachers understood the project to not only focus on developing new technology, but also on supporting new workplace practices.

Technology Comprehension

Piloting Technology Comprehension as an elective course revealed a crucial issue. The teachers did not have a shared understanding of Technology Comprehension as a learning subject, although the subject was already defined in the national curriculum. Instead, the teachers interpreted the subject through their personal beliefs, experiences, and interests. Teachers with design backgrounds emphasised design goals, teachers with computing backgrounds valued computing goals, and teachers with humanistic backgrounds tended societal goals. Hence, the learning goals of Technology Comprehension became individual skill sets for integration into other subjects, instead of a combination to form a distinct subject.

> We created a programming and math course, which starts in the first grade and runs through all grades. Programming is okay, but should not be a standalone subject, it

> should be part of the other subjects. A tool.
>
> I think a lot about how it can be part of natural science subjects. Currently, I am also teaching crafts, where I think that it could fit in. But, as I said, I also think that having it as a part of natural sciences would be very exciting for me.
>
> I tend to focus on the design part of the subject because that is what I find awesome, this entrepreneurship, and I try to give tasks like 'Design a logo', 'Find a company name', 'Create a business model'.
>
> This new thing that is starting, I think about it as part of the existing subjects.

The teachers' main concern was how to engage all students in Technology Comprehension. They worried whether the students would possess the required skills so that the subject could be taught in a meaningful way. If the subject were introduced in the seventh grade, for example, the prerequisites would need to be very low. Otherwise, any lack of basic skills, such as basic computer use, would prevent the students from focusing on the actual learning activities. Further, teaching the basic skills during the class would leave little time for other learning objectives. Another concern was that students have different needs regarding structure and guidance. Some students want to be challenged and to be provided with less guidance, while others are incapable of acting without clear instructions.

> I have some boys in my elective course and even before I started the teaching they had downloaded the files we should use. At the same time, I had a girl who did not know what a file is. The students had very different skills for participating in this field.
>
> I would like to be better at presenting the students with a problem as a starting point, where they can analyse, design and develop. Currently, they have mostly worked with learning the different technologies.
>
> Some of them expect to be challenged, some of them expect to get everything served on a silver plate. That is one of the biggest concerns I have to get them to be better.
>
> A lot of students want to participate in 4-6th grade, in 7-9th grade, it is primarily boys.

To engage students in Technology Comprehension, the teachers proposed student-centred learning activities that focused on topics relevant for the students. For example, a teacher described how ninth graders developed a sense of ownership towards the design task. The students' task was to make math games for first graders, and the students used their breaks to test the games to assure that the games were not too difficult.

> We were making math games with Scratch, it was obvious that older students had a sense of ownership to this assignment. The 9th graders were supposed to make a math game for 1st graders. The day before, 9th graders used their lunch break to go to 1st graders and check if the level was too hard. Then 9th graders went back and adjusted the games. That's very uncommon to 9th graders to do something like that in own time.
>
> My focus is to have a starting point that the students can relate to, for example, in the Odense municipality we are establishing the new light-rail. The students were concerned about what if a blind person should cross the light-rail, can we be sure that the train will stop. So they tried to build some censors with Micro:bits. This was the classical problem-solving setting that the students could relate to.

The teachers appreciated that the subject combined computing, design, and societal reflection. They stated that computing-related curricula are often designed by people with computing backgrounds, and as such learning objectives are often restricted to computing goals. Technology Comprehension opens up to holistic learning goals when it is designed by stakeholders with various backgrounds.

4.3 Issues in involving teachers

This section presents the issues that were identified during the two projects.

Identifying roles, needs, rights, and responsibilites

The first issue involved identifying roles, needs, rights, and responsibilities. In the ONSPACE project, the main roles were teachers, researchers, developers, and technical staff. The teachers needed to solve the problem that the new school had: how to organise everyday life in the new school without any dedicated classrooms. The researchers' need was to study the project and obtain international funding. The developers needed to deliver a working system that met the defined requirements, whereas the technical staff needed to make sure that the security of the system could not be compromised. Issue arose when these needs conflicted. First, ignoring the needs of administrative staff resulted in serious deficiencies when putting the system into production. This was solved by assigning a freelance software developer to implement the missing features. Second, after the design stage, not enough attention was paid to deciding what features would be realistic to develop. This resulted in expectations that were too optimistic for the resources available for development.

In the Technology Comprehension project, the main stakeholder roles were teachers, project staff, and researchers. In this case, the teachers did not have a single common need. Some were enthusiastic about developing the subject, some hoped to learn about the subject topics (e.g. programming), and some called for support to organise the elective course. The project staff needed to deliver the outcomes that the Ministry of Education had defined. When regarding the researcher role, the author's need was to conduct research for the dissertation. In the end, there appeared a contradiction between the author's need to conduct research and the project staff's need to minimise pressure on the teachers. The author was supposed to interview the teachers for the dissertation, but the teachers signaled that the interviews would take more time than they had available for the project. Thus, it was agreed to leave the interviews out, so that the teachers did not become overburdened.

In addition to identifying the roles and needs, it is crucial to negotiate the rights and responsibilities of project outcomes, such as produced technologies or data. There was a misunderstandment regarding the system maintenance responsibility in the ONSPACE project. The technical staff assumed that they were to install the system, and the faculty members were responsible for fixing possible errors and updates. However, transferring the system rights meant that faculty were no longer responsible for the system. In the end, the problem was solved when the developers agreed to remain available for consultation should problems appear when deploying the system in the school.

Participation as a possibility instead of an obligation

This dissertation focuses on teachers, so participation was examined from the teacher perspective. A teacher's core work includes lesson planning, teaching, and assessing. In addition, teachers have a lot of out-of-classroom work: solving disputes between students, communicating with parents, and organising activities such as trips and sports events. Teachers are also required to take part in school boards, parent evenings, multidisciplinary expert groups, and school welfare groups. Thus, any additional project may appear as something that just takes time and attention away from the most essential – being with students. PD requires a lot of time and resources, such as being present in design activities and familiarising with new people, technologies, and concepts. It is important to make sure that the PD initiative does not exploit the responsibility and accountability often observed in teachers.

The ONSPACE project was justified for teachers by emphasising that the system would be owned by the school and not by the university or some other party. Moreover, the project sought to develop a system based on teachers' needs instead of asking teachers to adapt their work practices. However, how the teachers would benefit from participating in the project was not considered directly; it was assumed that developing the system would automatically lead to outcomes that benefit teachers.

The Technology Comprehension project had a two-fold goal: to examine the implementation of the new subject and to envision support for teachers. The practical implication was that the project activities were configured from a premise that the teachers should receive personal benefits from participating in the project. During the interviews and the school visits, the teachers expressed that they would benefit from professional training about the learning objectives of Technology Comprehension. The workshop programme was thus added to include lectures about design, computational thinking, and hands-on tasks with Micro:bits. This allowed the teachers to get something useful out of providing information.

Clarifying an agenda for sustainable outcomes

The final issue to overcome is to construct compelling arguments as to why it is necessary to allocate resources for PD. If the agenda is left vague, the feasibility of the project is easily questioned. For example, one might ask why the learning space management system was not simply ordered from a professional software company, or why the best practices for Technology Comprehension are not developed in teacher education departments?

In the ONSPACE project, the key problem was to anticipate how to organise work practices in the new school without traditional classrooms. Developing the system was not so much a necessity itself, but rather the most promising way to solve the problem. In the Technology Comprehension project, the agenda was to examine the implementation of the new subject. This included understanding teachers' work conditions, challenges, and capabilities.

Despite the fact that both of the two projects put significant effort on sustainability, they ended up in opposite trajectories. The ONSPACE project aimed for international scope and applied for Horizon2020 Research and Innovation Action funding. The project was showcased in the Horizon2020 Proposers Day and received partnership proposals from several universities, companies, and non-governmental organisations. The established international initiative included three universities, two special education schools (including the Valteri School Onerva), and four companies. However, after the funding request from Horizon2020 was rejected both in 2014 and 2015, the international initiative was closed down.

The Technology Comprehension project has evolved in that the new subject is being integrated as a mandatory programme for lower secondary education in Denmark. The learning objectives comprise four competence areas: digital design and design processes, computational thinking, digital empowerment, and technological abilities. Between 2019 and 2022, 46 Danish schools will experiment with the programme either by integrating it into existing subjects or establishing it as an independent subject [1]; and these experiments will be further investigated by the project.

These opposite trajectories occurred for two reasons. First, the ONSPACE project was not able to communicate the value of its agenda. Even though the focus of the project was on *what the teachers want to achieve*, instead of *what the system should do*, it appeared too much as a standard software development project. Because the research was published in technically-oriented venues, the contemplated pedagogical possibilities of the new spaces, and how to dissemenate good pedagogical practices, were left in the background. The value of the project was in pedagogical deliberations with the teachers, but the communication pointed to non-significant technology. In comparison, the Technology Comprehension project was able to justify its existence by asserting that all schools are different, so there exists no one-size-fits-all solution. Rather, it is necessary to investigate the subject in various contexts.

Second, the ONSPACE project offered no opportunity for potential communities to emerge. Configuring the project according to open-source principles could have attracted other potential stakeholders, such as other schools, research organisations, or software companies. When the system was developed with the resources of a single organisation, there was a much higher threshold for making the system publicly available. To the author's knowledge, the learning space system has been further developed within Valteri School Onerva, but without collaboration with other stakeholders.

[1] The Danish Learning Portal, accessed 15.3.2019

5 DISCUSSION AND CONCLUSION

Section 5.1 summarises the findings and connects them to previous PD research. Section 5.2 concludes the dissertation by considering PD as an approach for involving teachers as design partners. Section 5.3 examines the strengths and limitations of the dissertation. Section 5.4 reviews the dissertation in relation to ACM Ethical Codes, the Finnish National Board on Research Integrity, and responsible conduct within PD. Section 5.5 specifies the author's contributions in the individual studies.

5.1 Discussion of results

The three research questions were: For what purpose have studies in PD examined teachers? How are teachers' goals and concerns manifested through PD? What issues can be observed when involving teachers in PD?

RQ1: Current state of research in participatory design involving teachers

Systematic mapping produced an overview of the current research on participatory design involving teachers. The mapped studies were assigned into three categories: environments, practices, and technologies. The studies in the environments category involved teachers in designing physical buildings, as well as technologies integrated into the environment. The studies in the practices category considered professional communities, instructional planning, and professional development programmes. The studies in the technologies category designed assessment and monitoring tools, educational games, learning and teaching applications, and technology for special needs.

Previous mapping and systematic review studies about PD exhibit a narrower focus. Halskov and Hansen (2015, p.83) limited the scope to the *Proceedings of the Participatory Design Conference* between 1990 and 2012, and Nunes et al. (2016, p.408) limited theirs to the IEEE database and ACM Digital Library. Hence, PI is the first known attempt to systematically map the whole PD field and organise the studies into a thematic structure. Furthermore, the study contributed to the use of computational methods for literature mapping and demonstrated how these methods could assist researchers. PII revealed that many PD studies have been published in venues other than in Human–Computer Interaction journals and conferences. Thus, the mapping provides a basis for multidisciplinary research that accounts for the research corpus both in learning sciences and PD, as recommended by DiSalvo et al. (2017).

There are several opportunities for continuing the work in PI and PII. The clusters in PI were analysed based on descriptive information, such as the most frequent words. A more in-depth examination of the articles within the clusters would produce a better view of contemporary PD research. Furthermore, the collected references can be disseminated for the PD research community by developing a web interface based on Mendeley API. As for PII, analyses of the studies focused on mapping the research objectives, and the methods used in each study were tabulated. However, these data have yet to be synthesised and reported.

RQ2: Developing a pedagogical vision and communicating between political and local levels

Teachers' goals and concerns regarding the open and adaptable school and Technology Comprehension can be expressed according to two themes: PD for developing a pedagogical vision, and PD for communicating between political and local levels. A central notion in PD is that design can either support old practices or aim to change them (Ehn, 1988). The motivation in PD is to involve participants in envisioning alternative choices and influencing how these choices are pursued (Bødker, 2003; Iversen et al., 2012; Simonsen and Robertson, 2013; Bødker and Kyng, 2018). The teachers were involved in designing the learning space system before the new school was put into use. Hence, the new building represented an opportunity for change, and the teachers were enthusiastic about the possibilities that the school could provide. Moving to the new school was also a chance to identify challenges in the work practices of the old school and engage in negotiations to address these challenges.

When the teachers engaged in designing the system, they attempted to develop a pedagogical vision for the open and adaptable school. This vision was manifested by negotatiating the future practices for the new school. The vision included, for example, the goal of rejecting the convention of viewing certain spaces only for certain purposes, such as viewing sports facilities only for teaching sports. When the teachers negotiatied with other stakeholders, such as the researchers and developers, the vision served as a guidepost: conflicting propositions, opinions, and decisions were evaluated from the premises of the vision. This finding corroborates the works of Iversen et al. (2012), who outlined PD as a trajectory where participants emerge, develop, and ground their values.

The teachers' goals and concerns in the Technology Comprehension project point to a crucial issue regarding implementing curriculum reform in Denmark.

The policy-level vision in the curriculum contradicted that of the local teachers. Although the three learning objectives were combined as a single subject, the teachers based their visions for implementation on individual preferences, emphasising the objectives that related to their own backgrounds. Another concern was how to engage all students, with different backgrounds, skills, and needs, in Technology Comprehension. This concern related to the political decision as to in what grade the subject should be introduced. The Technology Comprehension project exemplifies an important aspect of participatory infrastructuring: the project served as a communication channel between political and local levels (Bødker et al., 2017; Smith and Iversen, 2018). By engaging with teachers, the project provided knowledge for politicians about the teachers' goals and concerns and, on the other hand, disseminated guidance and training about the new subject for the teachers.

RQ3: Building blocks of involving teachers as design partners

Analysing the issues in the two projects produced three themes: identifying roles, needs, rights, and responsibilies; participation as a possibility instead of an obligation; and setting an agenda for sustainable outcomes. These themes are common in PD literature, as can be seen in Chapter 2. The contribution here is that this discussion is contextualised within education, and specifically in terms of collaboration with teachers. Here, these themes are connected to the mapped studies to provide building blocks of involving teachers as design partners.

Identifying roles, needs, rights, and responsibilities is essential for PD (Bratteteig and Wagner, 2012; Iversen and Dindler, 2014; Barcellini et al., 2015). The ONSPACE project demonstrated that the more roles in the project, the larger the potential for conflicting needs, rights, or responsibilities. Although conflicts do not necessarily appear, anticipating this possibility prevents ending up in a situation where the stakeholders steer the project into opposite directions. The systematic mapping provides some valuable assets: visual tools for triangulating participants' different perspectives (Woolner et al., 2010), stakeholder analysis models (Könings et al., 2017), a tool for mapping and sharing stakeholders' goals (Janssen et al., 2017), and the stakeholder analysis framework (Bossavit and Parsons, 2016). When regarding the involvement of teachers and students, some studies recommended involving them together, while others proposed separating them. Casanova and Mitchell (2017) stated that dividing students and teachers into separate groups offers a more pleasant environment for both. Woolner et al. (2007) warned that the teachers perspective may be pushed to the background if students and teachers are in the same group. This would be an interesting point to explore further when investigating PD in an educational context.

Positioning participation as a possibility instead of an obligation involves anticipating the benefits of PD projects from the participants' perspectives (Vines et al., 2013; Frauenberger et al., 2015; Halskov and Hansen, 2015; Smith et al., 2017; Saad-Sulonen et al., 2018). Based on the literature mapping, the advantages of PD from the teacher perspective include: for example, opportunity to reflect teaching methods (Bossen et al., 2010), development of teacher ownership (Kyza and Georgiou, 2014), conditions that support teachers (Cober et al., 2015), and teacher's professional development (Kyza and Nicolaidou, 2017). Furthermore, some studies proposed PD as a way to deal with contradictions between teachers' pedagogical needs and other stakeholders' needs (van Merriënboer et al., 2017; Woolner et al., 2007) and to reduce discrepancies between teachers and students (Könings et al., 2007, 2010, 2011). Most of the mapped studies relied on the assumption that PD would indirectly benefit teachers, such as through building a better learning environment or developing better practices and technologies. Reliance on indirect benefits was observed in the ONSPACE project, whereas direct benefits for teachers were built into the Technology Comprehension project.

Sustaining outcomes is a central topic in contemporary PD research (Iversen and Dindler, 2014; Vines et al., 2015; Bødker et al., 2017; Bødker and Kyng, 2018; Saad-Sulonen et al., 2018; Smith and Iversen, 2018). In the ONSPACE project, the agenda became blurred because the pedagogical deliberations fell behind the technological interests, whereas the Technology Comprehension initiative was able to justify its importance. The mapping revealed examples of a clear agenda, such as promoting social mobility and greater professionalism in public schools (Bossen et al., 2010), facilitating teachers' professional development and social networking (Farooq et al., 2007), and developing teachers' ownership towards educational reforms (Kyza and Nicolaidou, 2017). The other issue in the ONSPACE project was that access to outcomes was closed, which did not allow communities to emerge. In the literature mapping, the studies that had long-lasting and wide impact were grounded in research collaboration (Könings et al., 2007, 2010, 2011; Cober et al., 2015; Burke and Könings, 2016; Könings et al., 2017; Janssen et al., 2017; Koutamanis et al., 2017, see), technological infrastructure (nine years of research about *Tapped In* Farooq et al., 2007), or pedagogical ideas (see *De Werkplaats* Burke and Könings, 2016; Koutamanis et al., 2017; van Merriënboer et al., 2017).

5.2 Conclusion

This dissertation examined PD as an approach for involving teachers as design partners. PD has become a well-known approach, especially when involving users in designing new technologies. PD is not a strictly defined framework, or a collection of methods, but rather a way of designing that incorporates own principles and values established in the PD community. The purpose of involving users is not only to inform design, but to give users agency and influence on what kind of products, services, and practices are designed. As such, users should have equal possibilities to take part in decision-making, among researchers, designers, developers, and other stakeholders.

PD was examined by producing an overview of the current state of research into studies involving teachers, and by taking part in two projects. The findings of these three parts are summarised in Figure 6.

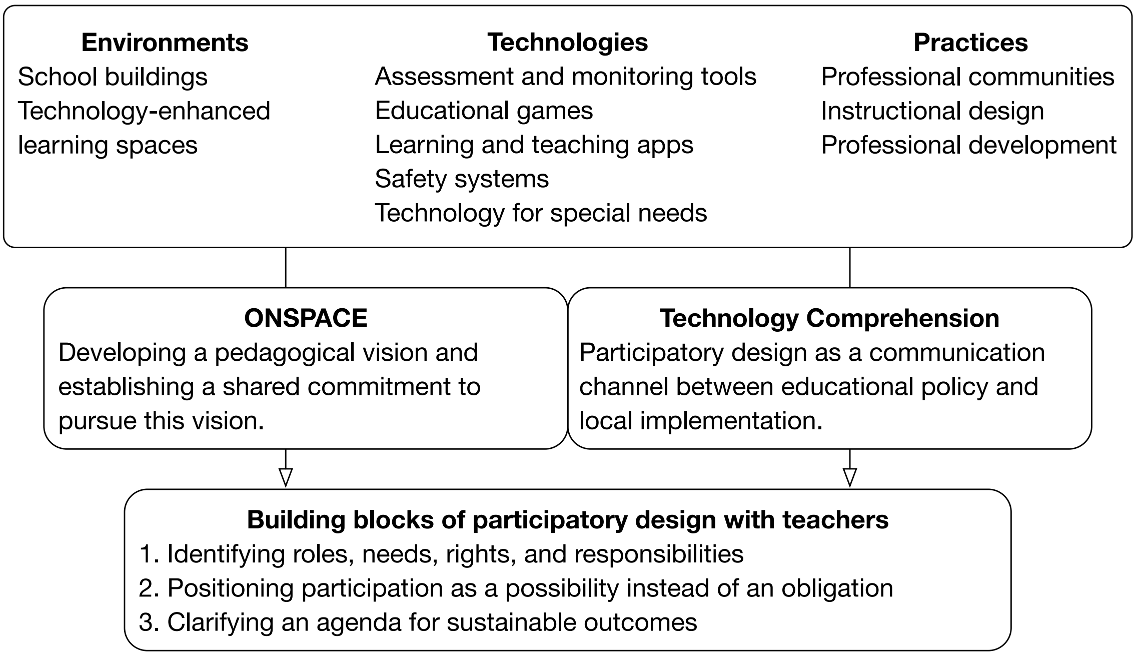

FIGURE 6 Interrelations between dissertation findings.

Systematic mapping produced three main areas in which PD advocates teacher involvement: designing learning environments, practices, and technologies. Taken together, these categories relate to two themes how technology pervades education. First, learning environments are expanding from classrooms to technology-enhanced spaces that are modifiable, flexible, and merge formal and informal learning (Kuuskorpi and Gonzalez, 2014). Second, education needs to provide skills not only to use technology but also understand how it works so that students develop the capacity to act as democratic, responsible, and critical individuals (Iversen et al., 2018). The implications of these two topics appear in the educational policies of the Nordic countries: governments are investing in new kinds of school facilities and implementing curriculum reforms that oblige teachers to incorporate computing subjects (Berge, 2017).

Involving teachers in the design of the learning space system for the open and adaptable school demonstrated how PD supports in developing a pedagogical vision and a shared commitment to pursue this vision (van Merriënboer et al., 2017, p. 266). Involving the whole school community in anticipating what changes the new environment might bring, and negotiating how the working and learning practices should be organised, requires a common ground where different needs are put into perspective. Of course, not all needs can be met, and developing the vision aids communication between stakeholders so that different options can be evaluated. The vision also prevents the introduction of technology that would become a barrier for the intended change. The technology must aid the objective of the project and operate well in the context for which it was developed. The project vision can be used to assess whether the technology supports or restricts the goals set for the new school.

The Technology Comprehension project demonstrated how PD served as a communication channel between local teachers and politicians. This relates to the three implementation strategies for educational reforms, presented by Pietarinen et al. (2017, p.25). In the top-down approach, school and teachers are considered as implementors of policy level decisions, while the bottom-up approach relies on the capacity of schools and teacher communities to develop these practices. The Technology Comprehension project examplified the interactive strategy: it brought together policy-level guidelines, resources, and networks with a local-level capacity to develop, evaluate, and provide knowledge. The new subject aimed to integrate computing and design skills as a means for understanding technology rather than learning outcomes. Engaging with teachers to pilot the subject demonstrated how the project prioritised their goals and concerns and provided information and training to best equip the teachers for success.

This dissertation proposes three building blocks of involving teachers as design partners based on the issues observed in the two projects and previous PD research with teachers. The first building block – identifying stakeholder roles, needs, rights, and responsibilities – aims to make transparent the reasons behind different decisions and to anticipate possible conflicts between different stakeholders. The second block aims to establish engagement by anticipating possible benefits from teacher's perspective and defining beforehand how these benefits are evaluated. The third block aims to clarify an agenda for sustainable outcomes, so that potential communities can emerge and continue the efforts of a PD project.

There are no silver bullets for how to involve teachers in design. That taken, PD still seems to provide an encouraging framework for conducting design projects in educational environments. For example, when schools are introducing new innovations, such as applications, devices, and services, a PD approach could be used to ensure that such innovations are designed to take teachers' working environment into account. Involving teachers in decision-making could prevent unwanted situations, in which innovations and teacher's everyday needs contradict and teachers need to change their practices to utilise these new innovations.

5.3 Quality and limitations

The quality assessment criteria for the literature mapping findings (RQ1) differ substantially from those of the two projects (RQ2 and RQ3). Literature reviews and mapping differ in purpose: mapping aims to gather a representative set of studies using inclusion and exlusion criteria, and then tabulates these studies into specific categories (see Kitchenham et al., 2010, p. 793 and Kitchenham and Charters, 2007, p. 44). From this angle, the quality of the study can be assessed based on how expansive and rigourous the mapping protocol is. For example, data collection in PI and PII should yield a similar collection of studies when executing the same search parameters and inclusion/exclusion criteria.

Both in PI and PII, the literature was collected from 14 academic search engines and databases, which is a very wide scope for a single mapping study. The data collection procedure can be repeated, which increases the reliability of the study. If data were to be collected now (2019), some studies would appear that are not in the original data. This is because new studies have been published since data collection for the present study was concluded in 2018. The exclusion criteria for PII have been explained in full and the reasons for exclusion recorded for each study. This makes external validation of the mapping possible.

However, when regarding the reliability of the results in PI and PII, it needs to be noted that producing the categories is not deterministic. In the former, the number of clusters in each clustering round was decided by the researcher, even though the Clustering Validation Indice recommends a set amount. The researcher also interpreted the cluster content, even though the algorithm provided information such as the most frequent words in a cluster. In the latter mapping, some of the studies could have been assigned to any of the three main categories. For example, So et al. (2009) examined teachers' professional development under the category of practices. This study could easily have incorporated the other two categories as well, as it involved online environments and the development of an online video platform.

Assessing the quality of the findings from the two projects is more complicated. These findings are strongly connected to the context in which the research was conducted (Spinuzzi, 2005; Frauenberger et al., 2015). Frauenberger et al. (2015) discuss the accountability and rigour of such results within the PD framework. Accountability is the transparency of expressing how PD led to certain outcomes: what happened and how it ended up. Rigour is the internal validitity of the statements derived through reflection and debate. Assessing trustworthiness is based on credibility, dependability, transferability, conformability (Frauenberger et al., 2015). Credibility refers to a participant's internal acceptance of outcomes, as well as the external believability of the outcomes based on provided evidence. Transefarability and dependability imply that evaluating the applicability of findings requires an understanding of how the findings depend on context, whereas conformability asks whether the provided evidence can be confirmed.

Findings related to RQ2 stem from interpretations of the teachers' interactions during the two projects. As such, the presented goals and concerns represent a consensus rather than unique opinions, the latter of which could have been better examined by surveying each teacher individually. The findings exemplify the knowledge construction in research through design (Zimmerman et al., 2007, 2010). The goals and concerns emerged when the teachers engaged in deliberating problems that were relevant to themselves and in their current context (cf. dialogic space in Iversen and Dindler, 2013; Bannon et al., 2018). These goals and concerns have been internally validated, as the other researchers in the two projects participated in analysing and confirming the findings. In comparison, the identified issues for the third research question emerged from the author's personal experiences. While events like the rejection of Horizon2020 funding can be confirmed, the credibility of the offered reasons and evidence must be left for others to evaluate.

There are three main limitations. First, because of the practical reasons related to funding, moving from one project to another limited the possibility for long-term research. Second, narrowing the scope to teachers kept the dissertation focused, but was artificial at times: there are no teachers without students. Neither of the projects involved students, as this could have been problematic with the chosen scope. Third, defining what is PD and is not can be somewhat ambigious: for some, each workshop where stakeholders take part in design is PD, and for others, only projects with a political mission genuinely represent PD.

5.4 Ethical considerations

The ethical aspects of the dissertation are reviewed here in relation to the guidelines for responsible conduct of research by the Finnish National Board on Research Integrity (2018, p. 30–31), Code of Ethics and Professional Conduct of the Association for Computing Machinery [1], and the ethical considerations within the PD research community. When regarding the published articles, all authors contributed in conducting and reporting research. For every publication, each author signed the agreement for publishing, and that they are accountable for all aspects of the work. Those who assisted in conducting research, as well as the study participants, were acknowledged in each publication.

The ethical aspects of the literature mapping relate most notably to the data collection and analysis. The search parameters, used search engines and databases, and data refinement protocols in PI and PII are desrcibed in detail. The collected references and articles were stored in a private database. Furthermore, the applied software tools and program code were described in both publications, and data is available on request.

In the ONSPACE project, the data management plan and consent documents were made according to the guidelines of the University of Jyväskylä. The data management plan informed what data was collected from the project into a register, who was responsible for the register, how data in the register was anonymised, where the register was located, and how the register was secured. Consent to conduct research was collected from each participant. The consent documents provided information about the research organisation, the purpose of the study, methods, possible benefits and disadvantages for participants, participants' rights, and asked participants to register their agreement. The project funding was described in the publication acknowledgements. In the Technology Comprehension project, data about study participants was anonymised and stored securely by the project staff. Each participant formally agreed to the research, and the participants were provided with information about the research purposes, methods, and participants' rights.

[1] Association for Computing Machinery, accessed 17.3.2019

The development of the learning space system in the ONSPACE project followed recommended practices in software engineering. The use of open-source libraries is documented in the system specifications. The development process was documented in a private version control system. The system was tested in a private server, and no data about the project participants was used in the testing stage. The system rights transfer agreement was made between stakeholder organisations. When the system rights were transfered, all development material was provided to the owner.

Part of pursuing the Doctor of Philosophy degree is to learn the academic conventions for responsible conduct of research, such as abstaining from fabrication, misrepresentation, plagiarism, or misappropriation. Furthermore, responsible conducting in PD requires accountability of design and research for local communities and pursuing professional growth (Robertson and Wagner, 2012; Steen, 2013). The author endeavoured to engage in two projects, become acquainted with PD literature, and network with other senior and junior researchers in the PD field. Valuable learning points included the doctoral course Values-led Participatory Design with Children (2015), the doctoral colloquium in Participatory Design Conference (2016), the doctoral course Designing Human Technologies (2017), and the annual summer meeting of Participatory Information Technology research group (2017).

5.5 Author's contributions

The following contributions have been reviewed based on the recommendations for authorship agreement in the (Finnish National Board on Research Integrity, 2018) and discussed in relation to research conception, data collection, and data analysis. The author was the corresponding author in each publication and had the most substantial role in drafting the research report.

PI: The author developed the idea and the scope for the mapping. The author executed the literature collection. The pre-processor was developed by Paavo Nieminen, which the author modified to work with the collected data. The clustering method was developed and executed by Tommi Kärkkäinen (Section 2.3 in PI). The author produced the cluster map and analysed the six education-related clusters. The author presented the article at the Participatory Design Conference.

PII: The study was conducted alone by the author.

PIII: The principal investigator of the project was Hannakaisa Isomäki. The author had no part in establishing the project or in developing the idea of utilising value-focused thinking as a requirement elicitation method. In the design stage, the author was involved in orchestrating the design activities and produced the system requirements specification. In the development stage, the author developed the system together with a project researcher, Toni Taipalus, and organised the design meetings. The author was responsible for data collection, except in the first meeting (Table 2 in PIII), and analysed data (Section 5.4 in PIII). The author presented the article at the International Conference of Computer Supported Education and was responsible for revising and extending the article for the Springer book *Communications in Computer and Information Science*.

PIV: The principal investigator of the project was Ole Sejer Iversen. The research design was based on the goals that were set for the project. The first survey and the interviews were conducted by the project researcher, Marie-Louise Wagner, as they were in Danish. The author was involved in some of the school visits and class observations. The workshops were facilitated by the project researchers, and the author recorded the workshops. The data collection and analysis regarding the self-assessment and feedback questionnaire were made by the author. The author designed the protocol for analysing the workshop recordings and was involved in the analysis with the other project members. The author presented the article at the Conference on Creativity and Making in Education – FabLearn Europe.

PV: When the article was revised for the special issue of the *International Journal of Child-Computer Interaction*, the author's responsibility was to extend the literature review (Section 2 in PV) together with Tommi Kärkkäinen. The additional findings (Section 5.3 in PV) were produced by Ole Sejer Iversen and Marie-Louise Wagner.

YHTEENVETO (FINNISH SUMMARY)

Väitöskirjassa tutkittiin osallistavaa suunnittelua opettajien kanssa tehtävän kehittämistyön lähestymistapana. Osallistavasta suunnittelusta on tullut suosittu lähestymistapa käyttäjien mukaan ottamiseksi erilaisten tuotteiden ja palveluiden suunnittelussa. Osallistava suunnittelu ei kuitenkaan ole tiukasti määritelty viitekehys, joka sisältäisi ennakkoon määrättyjä menetelmiä, vaan pikemminkin tutkimusyhteisössä muodostunut tapa tehdä suunnittelua ja kehittämistä omine periaatteineen ja arvopohjineen. Käyttäjien osallistamisen tarkoituksena ei ole ainoastaan saada tietoa käyttäjistä kehittämistyötä varten, vaan antaa käyttäjille mahdollisuus vaikuttaa siihen, millaisia tuotteita, palveluita ja käytäntöjä toteutetaan: käyttäjillä tulisikin olla tasavertaiset mahdollisuudet osallistua päätöksentekoon tutkijoiden, suunnittelujoiden ja sovelluskehittäjien kanssa. Selvimmiten tämä periaate on näkynyt tutkimuksissa, joissa vähemmistöedustajia, kuten maahanmuuttajanuoria, on otettu mukaan tekemään päätöksiä heille suunniteltavista tuotteista ja palveluista.

Väitöskirja sisältää kolme osaa. Ensimmäinen osa on systemaattinen kirjallisuuskartoitus opettajia koskevista osallistavan suunnittelun tutkimuksista viimeisen kymmenen vuoden ajalta. Neljästätoista eri hakukoneesta kerätyt tutkimukset analysoitiin ja sijoitettiin kolmeen eri kategoriaan: oppimisympäristöt, käytännöt ja teknologiat. Oppimisympäristöt sisälsivät kaksi osa-aluetta: koulurakennusten suunnittelu ja oppimisympäristöön integroitavien teknologioiden kehittäminen. Käytännöt liittyivät ammatillisten yhteisöjen muodostamiseen sekä opetusmenetelmien ja ammatillisten koulutusohjelmien suunnitteluun. Kolmannen kategorian teknologiat olivat arviointityökaluja, oppimispelejä, oppimis- ja opetusohjelmia, turvallisuusteknologioita sekä työkaluja erityistarpeita varten.

Toinen osa on Jyväskylän yliopiston informaatioteknologian tiedekunnan ja oppimis- ja ohjauskeskus Valteri Onervan kanssa yhteistyössä toteutettu kehittämishanke ONSPACE. Hankkeessa toteutettiin Valteri-koulu Onervan vuonna 2016 valmistuneeseen uuteen toimipisteeseen oppimistilojen hallintaan tarkoitettu mobiilisovellus. Sovelluksen tarkoituksena on tukea koulun *Oivallus – avautuva oppimistila* -tilakonseptia ja mahdollistaa oppimistilojen varaaminen karttapohjaisella visuaalisella käyttöliittymällä. Hankkeen aikana järjestettiin ennen uuden koulun käyttöön ottoa kahdeksan osallistavan suunnittelun työpajaa, joissa opettajat pohtivat pedagogisia tarpeitaan ja miten niihin voitaisiin vastata kehitettävällä teknologialla. Keskustelujen analysoinnin perusteella opettajat eivät ainoastaan osallistuneet sovelluksen vaatimusten määrittelyyn, vaan myös neuvottelivat koulun uudesta toimintakulttuurista ja tilojen käyttämisen periaatteista. Osallistavan suunnittelun työpajat olivatkin opettajille mahdollisuus neuvotella yhteisestä pedagogisesta visiosta sekä ennakoida uuden koulun mahdollisuuksia ja ongelmia.

Kolmas osa toteutettiin Aarhusin yliopistossa Tanskassa, vuoden mittaisen tutkimusvaihdon aikana. *Teknologiaymmärrys* -nimisessä kehittämishankkeessa kokeiltiin uutta valinnaista oppiainetta kolmessatoista tanskalaisessa yläkoulussa.

Tanskan opetusministeriön määrittelemän uuden oppiaineen tavoitteena on oppia suunnittelemaan digitaalisia tuotteita, toteuttamaan niitä ohjelmoimalla ja arvioimaan niiden yhteiskunnallisia vaikutuksia. Hankkeessa suoritettiin kouluvierailuja, oppiaineelle nimettyjen opettajien haastatteluja ja työpajoja. Työpajat sisälsivät täydennyskoulutusta opettajille sekä uuden oppiaineen toteuttamiseen liittyviä teemakeskusteluja. Hankkeen analysoinnin perusteella osallistava suunnittelu toimi viestintäkanavana opettajien ja poliittisten päättäjien välillä: opettajat välittivät huolenaiheitaan ja toiveitaan päätöksentekijöille ja toisaalta opettajat saivat tietoa ja koulutusta poliittisella tasolla määritellyistä vaatimuksista.

Kuviossa 7 väitöskirjan tulosten perusteella ehdotetaan kolmea toimenpidettä opettajien osallistamiseksi.

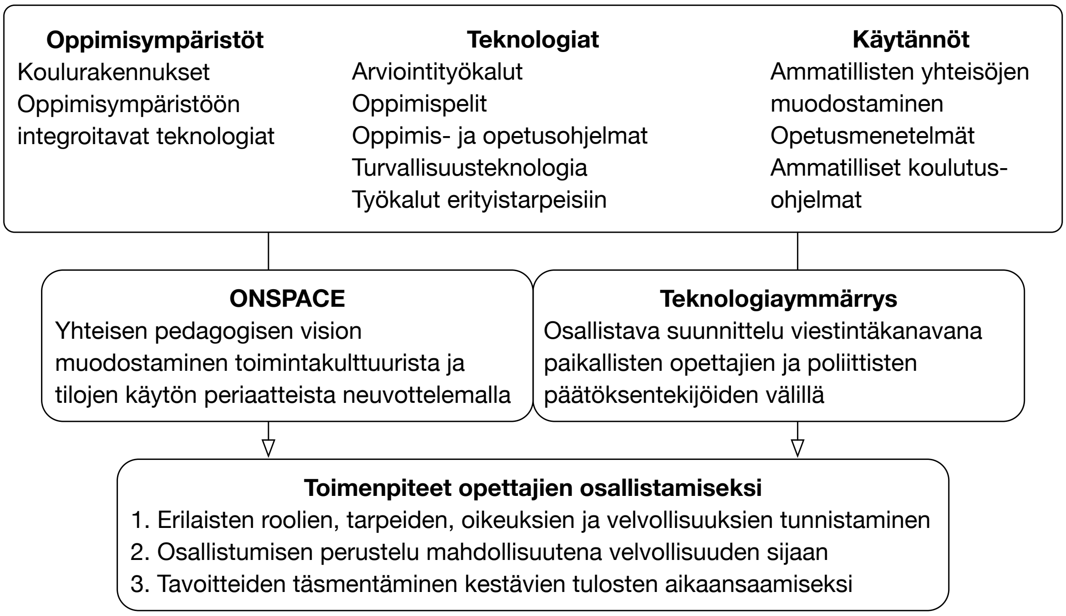

FIGURE 7 Conclusion in Finnish.

Ensiksikin, tulisi tunnistaa osallistujien erilaiset roolit, tarpeet, oikeudet ja velvollisuudet. Mitä useampia rooleja hankkeessa on sitä todennäköisempää että osallistujien tarpeet, oikeudet ja velvollisuudet ajautuvat keskenään ristiriitaan. Tämän ennakoiminen voi ehkäistä tilanteita, joissa eri osallistujaroolit ohjaavat hanketta vastakkaisiin suuntiin. Väitöskirjan kirjallisuuskartoituksella löydettiinkin erilaisia työkaluja näiden tekijöiden tunnistamiseksi. Toiseksi, hankkeeseen osallistuminen tulisi voida perustella opettajille mahdollisuutena velvollisuuden sijaan. Opettajien työnkuvaan kuuluu ennestäänkin paljon osallistumista, esimerkiksi oppilashuoltoryhmiin, vanhempainiltoihin ja luokkaretkien suunnitteluun. Kehittämishankkeeen ei pitäisi olla opettajalle vain uusi velvollisuus, vaan opettajille tulisi perustella kuinka he voivat hyötyä osallistumisestaan. Tähän voidaan pyrkiä kutsumalla opettajat ennakoimaan hankkeen mahdollisia hyötyjä ja miten hyödyt arvioidaan hankkeen aikana. Kolmanneksi, kehittämishankkeen tavoitteet tulisi täsmentää kestävien tulosten aikaansaamiseksi. Käytännössä tämä tarkoittaa sitä, että hankkeen tuloksena syntyy yhteisöjä, joissa hankkeen tavoitteita jatketaan ja joihin voi osallistua uusia toimijoita.

Opettajien osallistamiseen ei ole olemassa yhtä ainoaa oikeaa ratkaisua. Väitöskirjassa tutkittu osallistava suunnittelu näyttäisi kuitenkin tarjoavan mahdollisen viitekehyksen kouluympäristössä tehtäville kehittämishankkeille. Kun kouluissa otetaan käyttöön uusia innovaatioita, kuten sovelluksia, laitteita ja palveluja, osallistavan suunnittelun lähtökohtana olisi varmistaa, että nämä innovaatiot suunnitellaan yhteensopiviksi opettajien työskentely-ympäristöön. Ottamalla opettajat mukaan päätöksentekijöiksi voidaan ehkäistä tilanteita, joissa uudet innovaatiot ja opettajan arjen tarpeet eivät kohtaa, jolloin opettajat joutuvat mukauttamaan työtapojaan innovaatioiden käyttämiseksi.

REFERENCES

Abdullah, M. H. L. & Brereton, M. 2015. MyCalendar: Fostering Communication for Children with Autism Spectrum Disorder Through Photos and Videos. In Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI '15. New York, New York, USA: ACM Press, 1–9. doi:10.1145/2838739.2838785.

Admiraal, W., Louws, M., Lockhorst, D., Paas, T., Buynsters, M., Cviko, A., Janssen, C., de Jonge, M., Nouwens, S., Post, L., van der Ven, F. & Kester, L. 2017. Teachers in school-based technology innovations: A typology of their beliefs on teaching and technology. Computers & Education 114, 57–68. doi:10.1016/j.compedu.2017.06.013.

Al-Eraky, M. M., Donkers, J., Wajid, G. & van Merriënboer, J. J. 2015. Faculty development for learning and teaching of medical professionalism. Medical Teacher 37 (sup1), S40–S46. doi:10.3109/0142159X.2015.1006604.

Aldunate, R. & Nussbaum, M. 2013. Teacher adoption of technology. Computers in Human Behavior 29 (3), 519–524. doi:10.1016/j.chb.2012.10.017.

Andersen, L. B., Danholt, P., Halskov, K., Hansen, N. B. & Lauritsen, P. 2015. Participation as a matter of concern in participatory design. CoDesign 11 (3-4), 250–261. doi:10.1080/15710882.2015.1081246.

Anderson, L. & Östlund, D. 2017. Assessments for learning in grades 1-9 in a special school for students with intellectual disability in Sweden. Problems of Education in the 21st Century 75 (6), 508–524.

Bannon, L., Bardzell, J. & Bødker, S. 2018. Introduction. ACM Transactions on Computer-Human Interaction 25 (1), 1–8. doi:10.1145/3177794.

Barbera, E., Garcia, I. & Fuertes-Alpiste, M. 2017. A Co-Design Process Microanalysis: Stages and Facilitators of an Inquiry-Based and Technology-Enhanced Learning Scenario. The International Review of Research in Open and Distributed Learning 18 (6), 104–126. doi:10.19173/irrodl.v18i6.2805.

Barcellini, F., Prost, L. & Cerf, M. 2015. Designers' and users' roles in participatory design: What is actually co-designed by participants? Applied Ergonomics 50, 31–40. doi:10.1016/j.apergo.2015.02.005.

Beck, E. E. 2002. P for Political: Participation is Not Enough. Scandinavian Journal of Information Systems 14 (1), 77–92.

Berge, O. 2017. Rethinking Digital Literacy in Nordic School Curricula. Nordic Journal of Digital Literacy 12 (01-02), 5–7. doi:10.18261/issn.1891-943x-2017-01-02-01.

Bergvall-Kåreborn, B. & Ståhlbrost, A. 2008. Participatory design: one step back or two steps forward? In Proceedings of the Tenth Anniversary Conference on Participatory Design 2008, 102–111. doi:10.1145/1795234.1795249.

Bjerknes, G. & Bratteteig, T. 1995. User participation and democracy: a discussion of Scandinavian research on system development. Scandinavian Journal of Information Systems 7 (1), 73–98.

Bjerknes, G., Ehn, P. & Kyng, M. 1987. Computers and Democracy: A Scandinavian Challenge. Brookfield: Gower Press, 455.

Bjögvinsson, E., Ehn, P. & Hillgren, P.-a. 2012. Design Things and Design Thinking: Contemporary Participatory Design Challenges. Design Issues 28 (3), 101–116.

Booker, A. & Goldman, S. 2016. Participatory Design Research as a Practice for Systemic Repair: Doing Hand-in-Hand Math Research with Families. Cognition and Instruction 34 (3), 222–235. doi:10.1080/07370008.2016.1179535.

Bossavit, B. & Parsons, S. 2016. Designing an Educational Game for and with Teenagers with High Functioning Autism. In Proceedings of the 14th Participatory Design Conference: Full Papers - Volume 1. New York, NY, USA: ACM. PDC '16, 11–20. doi:10.1145/2940299.2940313.

Bossen, C., Dindler, C. & Iversen, O. S. 2010. User gains and PD aims. In Proceedings of the 11th Biennial Participatory Design Conference on - PDC '10. New York, New York, USA: ACM Press, 141. doi:10.1145/1900441.1900461.

Bratteteig, T. & Wagner, I. 2012. Disentangling power and decision-making in participatory design. In Proceedings of the 12th Participatory Design Conference on Research Papers: Volume 1 - PDC '12. New York, New York, USA: ACM Press, 41.

Bratteteig, T. & Wagner, I. 2016. Unpacking the Notion of Participation in Participatory Design. Computer Supported Cooperative Work (CSCW) 25 (6), 425–475. doi:10.1007/s10606-016-9259-4.

Bratteteig, T. 2003. Making change: Dealing with relations between design and use. University of Oslo. Ph. D. Thesis, 265.

Brereton, M., Sitbon, L., Abdullah, M. H. L., Vanderberg, M. & Koplick, S. 2015. Design after design to bridge between people living with cognitive or sensory impairments, their friends and proxies. CoDesign 11 (1), 4–20. doi:10.1080/15710882.2015.1009471.

Burke, C. & Könings, K. D. 2016. Recovering lost histories of educational design: a case study in contemporary participatory strategies. Oxford Review of Education 42 (6), 721–732. doi:10.1080/03054985.2016.1232244.

Bødker, K., Kensing, F. & Simonsen, J. 2004. Participatory IT Design - Designing for Business and Workplace Realities (First edition). Cambridge, Massachusetts: The MIT Press, 341.

Bødker, S., Dindler, C. & Iversen, O. S. 2017. Tying Knots: Participatory Infrastructuring at Work. Computer Supported Cooperative Work (CSCW) 26 (1-2), 245–273. doi:10.1007/s10606-017-9268-y.

Bødker, S., Ehn, P., Sjögren, D. & Sundblad, Y. 2000. Co-operative Design — perspectives on 20 years with ' the Scandinavian IT Design Model '. In NordiCHI 2000, 1–9.

Bødker, S. & Kyng, M. 2018. Participatory Design that Matters—Facing the Big Issues. ACM Transactions on Computer-Human Interaction 25 (1), 1–31. doi:10.1145/3152421.

Bødker, S. 1987. Through the Interface - a Human Activity Approach to User Interface Design. University of Aarhus. Ph. D. Thesis.

Bødker, S. 2003. A for Alternatives. Scandinavian Journal of Information Systems 15 (2002), 87–89.

Carmichael, P. 2015. Not just about gadgets: Habit, innovation and change in the design of learning technologies. E-Learning and Digital Media 12 (3-4), 279–294. doi:10.1177/2042753015571052.

Casanova, D. & Mitchell, P. 2017. The cube and the poppy: Participatory approaches for designing technology-enhanced learning spaces. Journal of Learning Spaces 6 (3), 1–12.

Clement, A. & Van den Besselaar, P. 1993. A retrospective look at PD projects. Communications of the ACM 36 (6), 29–37.

Cober, R., Tan, E., Slotta, J., So, H.-J. & Könings, K. D. 2015. Teachers as participatory designers: two case studies with technology-enhanced learning environments. Instructional Science 43 (2), 203–228. doi:10.1007/s11251-014-9339-0.

Cox, M. J. 2013. Formal to informal learning with IT: research challenges and issues for e-learning. Journal of Computer Assisted Learning 29 (1), 85–105. doi:10.1111/j.1365-2729.2012.00483.x.

Cramer, M. & Hayes, G. R. 2013. The digital economy. In Proceedings of the 12th International Conference on Interaction Design and Children - IDC '13. New York, New York, USA: ACM Press, 431–434. doi:10.1145/2485760.2485832.

Cross, N. 2001. Designerly Ways of Knowing: Design Discipline Versus Design Science. Design Issues 17 (3), 49–55.

Cruz-Jesus, F., Vicente, M. R., Bacao, F. & Oliveira, T. 2016. The education-related digital divide: An analysis for the EU-28. Computers in Human Behavior 56, 72–82.

Cviko, A., McKenney, S. & Voogt, J. M. 2014. Teacher roles in designing technology-rich learning activities for early literacy: A cross-case analysis. Computers & Education 72, 68–79. doi:10.1016/j.compedu.2013.10.014.

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

DiSalvo, B., Yip, J., Bonsignore, E. & DiSalvo, C. 2017. Participatory Design for Learning: Perspectives from Practice and Research (First edition). New york: Routledge, 268.

Druin, A. 2002. The role of children in the design of new technology. Behaviour & Information Technology 21 (1), 1–25. doi:10.1080/01449290110108659.

Duarte, A. M. B., Brendel, N., Degbelo, A. & Kray, C. 2018. Participatory Design and Participatory Research. ACM Transactions on Computer-Human Interaction 25 (1), 1–39.

Duell, C., Wright, N. & Roxburgh, J. 2014. Developing "Design Minds" for the 21st Century through a Public Sector Initiated Online Design Education Platform.

Ehn, P. 1988. Work-Oriented Design of Computer Artifacts. Umeå Universitat. Ph. D. Thesis.

Ertmer, P. a., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E. & Sendurur, P. 2012. Teacher beliefs and technology integration practices: A critical relationship. doi:10.1016/j.compedu.2012.02.001.

Ervasti, M., Laitakari, J. & Hillukkala, M. 2016. 'I want to know where my child is at all times' – field study of a location-aware safety service for schoolchildren. Behaviour & Information Technology 35 (10), 833–852. doi:10.1080/0144929X.2016.1201144.

Fage, C., Pommereau, L., Consel, C., Balland, E. & Sauzéon, H. 2016. Tablet-Based Activity Schedule in Mainstream Environment for Children with Autism and Children with ID. ACM Transactions on Accessible Computing 8 (3), 1–26. doi:10.1145/2854156.

Fage, C., Pommereau, L., Consel, C., Balland, É. & Sauzéon, H. 2014. Tablet-based activity schedule for children with autism in mainstream environment. In Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility - ASSETS '14. New York, New York, USA: ACM Press, 145–152.

Farooq, U., Schank, P., Harris, A., Fusco, J. & Schlager, M. 2007. Sustaining a Community Computing Infrastructure for Online Teacher Professional Development: A Case Study of Designing Tapped In. Computer Supported Cooperative Work (CSCW) 16 (4-5), 397–429. doi:10.1007/s10606-007-9049-0.

Frauenberger, C., Good, J., Fitzpatrick, G. & Iversen, O. S. 2015. In pursuit of rigour and accountability in participatory design. International Journal of Human-Computer Studies 74, 93–106. doi:10.1016/j.ijhcs.2014.09.004.

Gaver, W. 2012. What should we expect from research through design? In Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12. New York, New York, USA: ACM Press, 937.

Gavriushenko, M., Khriyenko, O. & Tuhkala, A. 2017. An Intelligent Learning Support System. In Proceedings of the 9th International Conference on Computer Supported Education, Vol. 1. SCITEPRESS - Science and Technology Publications, 217–225.

Gillies, M., Brenton, H., Yee-King, M., Grimalt-Reynes, A. & D'Inverno, M. 2015. Sketches vs skeletons. In Proceedings of the 2nd International Workshop on Movement and Computing - MOCO '15, Vol. 14-15-Augu. New York, New York, USA: ACM Press, 104–111. doi:10.1145/2790994.2790995.

Girard, S. & Johnson, H. 2010. Designing affective computing learning companions with teachers as design partners. In Proceedings of the 3rd international workshop on Affective interaction in natural environments - AFFINE '10. New York, New York, USA: ACM Press, 49. doi:10.1145/1877826.1877840.

Goeze, A., Zottmann, J. M., Vogel, F., Fischer, F. & Schrader, J. 2014. Getting immersed in teacher and student perspectives? Facilitating analytical competence using video cases in teacher education. Instructional Science 42 (1), 91–114. doi:10.1007/s11251-013-9304-3.

Greenbaum, J. & Kyng, M. (Eds.) 1991. Design at Work: Cooperative Design of Computer Systems. Hillsdale, NJ, USA: L. Erlbaum Associates Inc.

Greenbaum, J. 1993. PD a personal statement. Communications of the ACM 36 (6), 47. doi:10.1145/153571.214816.

Gregory, J. 2003. Scandinavian Approaches to Participatory Design. International Journal of Engaging Education 19 (1), 62–74.

Gros, B. & López, M. 2016. Students as co-creators of technology-rich learning activities in higher education. International Journal of Educational Technology in Higher Education 13 (1), 28. doi:10.1186/s41239-016-0026-x.

Grönvall, E. & Kyng, M. 2013. On participatory design of home-based healthcare. Cognition, Technology & Work 15 (4), 389–401.

Hall, R., Atkins, L. & Fraser, J. 2014. Defining a self-evaluation digital literacy framework for secondary educators: the DigiLit Leicester project. Research in Learning Technology 22. doi:10.3402/rlt.v22.21440.

Halskov, K. & Hansen, N. B. 2015. The diversity of participatory design research practice at PDC 2002–2012. International Journal of Human-Computer Studies 74, 81–92. doi:10.1016/j.ijhcs.2014.09.003.

Hannon, D., Danahy, E., Schneider, L., Coopey, E. & Garber, G. 2012. Encouraging teachers to adopt inquiry-based learning by engaging in participatory design. In IEEE 2nd Integrated STEM Education Conference. Department of Mechanical Engineering/Human Factors, Tufts University, United States: IEEE, 1–4. doi:10.1109/ISECon.2012.6204169.

Harrison, C. J., Könings, K. D., Schuwirth, L. W. T., Wass, V. & van der Vleuten, C. P. M. 2017. Changing the culture of assessment: the dominance of the summative assessment paradigm. BMC Medical Education 17 (1), 73. doi:10.1186/s12909-017-0912-5.

Herstad, J. & Holone, H. 2012. What we talk about when we talk about co-creative tangibles. In Proceedings of the 12th Participatory Design Conference on Exploratory Papers Workshop Descriptions Industry Cases - Volume 2 - PDC '12. New York, New York, USA: ACM Press. PDC '12, 109. doi:10.1145/2348144.2348179.

Hoda, R., Henderson, A., Lee, S., Beh, B. & Greenwood, J. 2014. Aligning technological and pedagogical considerations: Harnessing touch-technology to enhance opportunities for collaborative gameplay and reciprocal teaching in NZ early education. International Journal of Child-Computer Interaction 2 (1), 48–59. doi:10.1016/j.ijcci.2014.06.001.

Hsu, S. 2017. Developing and validating a scale for measuring changes in teachers' ICT integration proficiency over time. Computers & Education 111, 18–30. doi:10.1016/j.compedu.2017.04.001.

Hussain, S. 2010. Empowering marginalised children in developing countries through participatory design processes. CoDesign 6 (2), 99–117. doi:10.1080/15710882.2010.499467.

Iivari, J. & Iivari, N. 2006. Varieties of User-Centeredness. In Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06), Vol. 8. IEEE, 176a–176a. doi:10.1109/HICSS.2006.530.

Ishimaru, A. M. & Takahashi, S. 2017. Disrupting Racialized Institutional Scripts Toward Parent-Teacher Transformative Agency for Educational Justice. Peabody Journal of Education 92 (3), 343–362. doi:10.1080/0161956X.2017.1324660.

Iversen, O. S. & Dindler, C. 2013. A Utopian agenda in child-computer interaction. International Journal of Child-Computer Interaction 1 (1), 24–29. doi:10.1016/j.ijcci.2012.08.002.

Iversen, O. S. & Dindler, C. 2014. Sustaining participatory design initiatives. CoDesign 10, 153–170. doi:10.1080/15710882.2014.963124.

Iversen, O. S., Halskov, K. & Leong, T. W. 2012. Values-led participatory design. CoDesign 8 (2-3), 87–103. doi:10.1080/15710882.2012.672575.

Iversen, O. S., Smith, R. C. & Dindler, C. 2017. Child as Protagonist: Expanding the Role of Children in Participatory Design. Proceedings of the 2017 Conference on Interaction Design and Children - IDC '17, 27–37.

Iversen, O. S., Smith, R. C. & Dindler, C. 2018. From computational thinking to computational empowerment. In Proceedings of the 15th Participatory Design Conference on Full Papers - PDC '18. New York, New York, USA: ACM Press, 1–11.

Janssen, F., Könings, K. D. & van Merriënboer, J. J. 2017. Participatory educational design: How to improve mutual learning and the quality and usability of the design? European Journal of Education 52 (3), 268–279. doi:10.1111/ejed.12229.

Janssen, F. J. J. M., Westbroek, H. B. & van Driel, J. H. 2014. How to make guided discovery learning practical for student teachers. Instructional Science 42 (1), 67–90. doi:10.1007/s11251-013-9296-z.

Joyce, C., Pham, H., Stanton Fraser, D., Payne, S., Crellin, D. & McDougall, S. 2014. Building an internet of school things ecosystem. In Proceedings of the 2014 conference on Interaction design and children - IDC '14. New York, New York, USA: ACM Press, 289–292. doi:10.1145/2593968.2610474.

Jutila, M., Strömmer, E., Ervasti, M., Hillukkala, M., Karhula, P. & Laitakari, J. 2015. Safety services for children: a wearable sensor vest with wireless charging. Personal and Ubiquitous Computing 19 (5-6), 915–927. doi:10.1007/s00779-015-0838-z.

Kalra, N., Lauwers, T., Dewey, D., Stepleton, T. & Dias, M. B. 2007. Iterative design of a Braille writing tutor to combat illiteracy. In 2007 International Conference on Information and Communication Technologies and Development. RAND corporation, United States: IEEE, 1–9. doi:10.1109/ICTD.2007.4937386.

Karasti, H. 2014. Infrastructuring in participatory design. In Proceedings of the 13th Participatory Design Conference on Research Papers - PDC '14. New York, New York, USA: ACM Press, 141–150.

Karimi, A., Worthy, P., McInnes, P., Bodén, M., Matthews, B. & Viller, S. 2017. The Community Garden Hack: Participatory Experiments in Facilitating Primary School Teacher's Appropriation of Technology. In Proceedings of the 29th Australian Conference on Computer-Human Interaction. New York, NY, USA: ACM. OZCHI '17, 143–151. doi:10.1145/3152771.3152787.

Kelentric, M., Helland, K. & Arstorp, A.-T. 2017. Professional Digital Competence Framework for Teachers.

Kensing, F. & Blomberg, J. 1998. Participatory Design: Issues and Concerns. Computer Supported Cooperative Work (CSCW) 7 (3-4), 167–185. doi:10.1023/A:1008689307411.

Kensing, F. & Greenbaum, J. 2013. Heritage - Having a say. In J. Simonsen & T. Robertson (Eds.) Routledge International Handbook of Participatory Design. New York: Routledge, 21–36. doi:10.4324/9780203108543.ch2.

Kitchenham, B. & Charters, S. 2007. Guidelines for performing Systematic Literature reviews in Software Engineering, 57. doi:10.1145/1134285.1134500.

Kitchenham, B., Pretorius, R., Budgen, D., Brereton, O. P., Turner, M., Niazi, M. & Linkman, S. 2010. Systematic literature reviews in software engineering-A tertiary study. Information and Software Technology 52 (8), 792–805. doi:10.1016/j.infsof.2010.03.006.

Klonari, A. & Gousiou, A. 2014. Encouraging teachers' reflection using a card game: The game of consequences. In Proceedings of the European Conference on Games-based Learning, Vol. 1. Dept of Geography, University of the Aegean, Mytilene, Greece: , 279–285.

Koutamanis, A., Heuer, J. & Könings, K. D. 2017. A visual information tool for user participation during the lifecycle of school building design: BIM. European Journal of Education 52 (3), 295–305. doi:10.1111/ejed.12226.

Kreitmayer, S., Rogers, Y., Laney, R. & Peake, S. 2013. UniPad: Orchestrating Collaborative Activities Through Shared Tablets and An Integrated Wall Display. In Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing - UbiComp '13. New York, New York, USA: ACM Press, 801. doi:10.1145/2493432.2493506.

Krumsvik, R. J. 2014. Teacher educators' digital competence. Scandinavian Journal of Educational Research 58 (3), 269–280. doi:10.1080/00313831.2012.726273.

Kuure, L., Molin-Juustila, T., Keisanen, T., Riekki, M., Iivari, N. & Kinnula, M. 2016. Switching perspectives: from a language teacher to a designer of language learning with new technologies. Computer Assisted Language Learning 29 (5), 925–941. doi:10.1080/09588221.2015.1068815.

Kuuskorpi, M. & Gonzalez, N. C. 2014. Physical learning environments: learning in the future. In M. Kuuskorpi (Ed.) Perspectives from finland towards new learning environment. Tampere: Juvenes Print, Suomen Yliopistopaino Oy, 63–77.

Kuuskorpi, M. 2012. Future physical learning environment. User oriented exible and changeable teaching spaces. University of Turku. Dissertation.

Kyza, A. E. & Georgiou, Y. 2014. Developing In-Service Science Teachers' Ownership of the Profiles Pedagogical Framework through a Technology-Supported

Participatory Design Approach to Professional Development. Science Education International 25 (2), 21.

Kyza, E. A. & Nicolaidou, I. 2017. Co-designing reform-based online inquiry learning environments as a situated approach to teachers' professional development. CoDesign 13 (4), 261–286. doi:10.1080/15710882.2016.1209528.

Könings, K. D., Bovill, C. & Woolner, P. 2017. Towards an interdisciplinary model of practice for participatory building design in education. European Journal of Education 52 (3), 306–317. doi:10.1111/ejed.12230.

Könings, K. D., Brand-Gruwel, S. & van Merriënboer, J. J. 2007. Teachers' perspectives on innovations: Implications for educational design. Teaching and Teacher Education 23 (6), 985–997. doi:10.1016/j.tate.2006.06.004.

Könings, K. D., Brand-Gruwel, S. & van Merriënboer, J. J. 2010. An approach to participatory instructional design in secondary education: an exploratory study. Educational Research 52 (1), 45–59. doi:10.1080/00131881003588204.

Könings, K. D., Brand-Gruwel, S. & van Merriënboer, J. J. 2011. Participatory instructional redesign by students and teachers in secondary education: effects on perceptions of instruction. Instructional Science 39 (5), 737–762. doi:10.1007/s11251-010-9152-3.

Könings, K. D., van Zundert, M. J., Brand-Gruwel, S. & van Merriënboer, J. J. 2007. Participatory design in secondary education: is it a good idea? Students' and teachers' opinions on its desirability and feasibility. Educational Studies 33 (4), 445–465. doi:10.1080/03055690701423648.

Lawrence, S. A. & Calhoun, F. 2013. Exploring Teachers ' Perceptions of Literacy and Use of Technology in Classroom Practice : Analysis of Self-Reported Practice in One School District. Journal of Literacy and Technology 14 (1), 51–71.

Leong, T. W. & Iversen, O. S. 2015. Values-led Participatory Design as a Pursuit of Meaningful Alternatives. In Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI '15. New York, New York, USA: ACM Press, 314–323. doi:10.1145/2838739.2838784.

Lindtner, S. & Lin, C. 2017. Making and its promises. CoDesign 13 (2), 70–82.

Lingnau, A. & Lenschow, H. 2010. Scenarios for computersupported learning in a special needs classroom. Journal of Assistive Technologies 4 (2), 26–35. doi:10.5042/jat.2010.0279.

Lundström, A., Savolainen, J. & Kostiainen, E. 2016. Case study: developing campus spaces through co-creation. Architectural Engineering and Design Management 12 (6), 409–426. doi:10.1080/17452007.2016.1208077.

Malinverni, L., Mora-Guiard, J. & Pares, N. 2016. Towards methods for evaluating and communicating participatory design: A multimodal approach. International Journal of Human-Computer Studies 94, 53–63.

Mama, M. & Hennessy, S. 2013. Developing a typology of teacher beliefs and practices concerning classroom use of ICT. Computers & Education 68 (0), 380–387. doi:10.1016/j.compedu.2013.05.022.

Medeiros-Braz, L., Souza Ramos, E., Benedetti, M. L. P. & Hornung, H. 2017. Participatory Design of Technology for Inclusive Education: A Case Study. In Lecture Notes in Computer Science, Vol. 10279 LNCS. Campinas: Springer Verlag, 168–187. doi:10.1007/978-3-319-58700-4.

van Merriënboer, J. J., McKenney, S., Cullinan, D. & Heuer, J. 2017. Aligning pedagogy with physical learning spaces. European Journal of Education 52 (3), 253–267. doi:10.1111/ejed.12225.

Mishra, P. & Koehler, M. 2006. Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. Teachers College Record 108 (6), 1017–1054.

Muller, M. J. 1991. PICTIVE - An exploration in participatory design. In Proceedings of the SIGCHI conference on Human factors in computing systems Reaching through technology - CHI '91. New York, NY, USA: ACM. CHI '91, 225–231.

Nevari, J. 2013. Oivaltamo: avautuva oppimistila. Lahti University of Applied Sciences. Ph. D. Thesis.

Ng, W. 2015. Change and Continuity in Educational Uses of New Digital Technologies. In New Digital Technology in Education. Cham: Springer International Publishing, 3–23.

Nieminen, P., Pölönen, I. & Sipola, T. 2013. Research literature clustering using diffusion maps. Journal of Informetrics 7 (4), 874–886.

Nunes, E. P. S., Luz, A. R., Lemos, E. M. & Nunes, C. 2016. Approaches of Participatory Design in the Design Process of a Serious Game to Assist in the Learning of Hospitalized Children. doi:10.1007/978-3-319-39513-5.

OECD 2015. Education Policy Outlook 2015: Making Reforms Happen.

OECD 2016. PISA 2015 Results (Volume I): Excellence and Equity in Education.

Otero, N., Alissandrakis, A., Müller, M., Milrad, M., Lencastre, J. A., Casal, J. & José, R. 2013. Promoting secondary school learners' curiosity towards science through digital public displays. In Proceedings of International Conference on Making Sense of Converging Media - AcademicMindTrek '13. New York, New York, USA: ACM Press, 204–210. doi:10.1145/2523429.2523475.

Owston, R. 2007. Teachers can make a difference : Professional development as a policy option for improving student learning with ICT. In CERI-KERIS International Expert Meeting On ICT and Educational Performance, 1–6.

Pantsar-Syväniemi, S., Ervasti, M., Karppinen, K., Väätänen, A., Oksman, V. & Kuure, E. 2015. A situation-aware safety service for children via participatory design. Journal of Ambient Intelligence and Humanized Computing 6 (2), 279–293. doi:10.1007/s12652-014-0225-z.

Parsons, S. & Cobb, S. 2014. Reflections on the role of the 'users': challenges in a multi-disciplinary context of learner-centred design for children on the autism spectrum. International Journal of Research & Method in Education 37 (4), 421–441. doi:10.1080/1743727X.2014.890584.

Parsons, S., Millen, L., Garib-Penna, S. & Cobb, S. 2011. Participatory design in the development of innovative technologies for children and young people on the autism spectrum: the COSPATIAL project. Journal of Assistive Technologies 5 (1), 29–34. doi:10.5042/jat.2011.0099.

Pedersen, J. B., Andersen, A. S. Ö. & Majgaard, G. 2012. Design of trigonometry apps for vocational education. In Proceedings of the IASTED International Conference on Human-Computer Interaction, HCI 2012. Itai a/s, Ndr. Landevej 2a, DK-6270 T{ø}nder, Denmark: , 226–232. doi:10.2316/P.2012.772-020.

Pietarinen, J., Pyhältö, K. & Soini, T. 2017. Large-scale curriculum reform in Finland – exploring the interrelation between implementation strategy, the function of the reform, and curriculum coherence. The Curriculum Journal 28 (1), 22–40.

Pilemalm, S. 2018. Participatory Design in Emerging Civic Engagement Initiatives in the New Public Sector. ACM Transactions on Computer-Human Interaction 25 (1), 1–26. doi:10.1145/3152420.

Pollock, M. & Amaechi, U. 2013. Texting as a channel for personalized youth support: participatory design research by city youth and teachers. Learning, Media and Technology 38 (2), 128–144. doi:10.1080/17439884.2013.756516.

Pontual-Falcão, T., Mendes de Andrade e Peres, F., Sales de Morais, D. C. & da Silva Oliveira, G. 2018. Participatory methodologies to promote student engagement in the development of educational digital games. Computers & Education 116, 161–175. doi:10.1016/j.compedu.2017.09.006.

Prins, G., Bulte, A. & Pilot, A. 2016. An Activity-Based Instructional Framework for Transforming Authentic Modeling Practices into Meaningful Contexts for Learning in Science Education. Science Education 100 (6), 1092–1123. doi:10.1002/sce.21247.

Pérez-Sanagustín, M., Nussbaum, M., Hilliger, I., Alario-Hoyos, C., Heller, R. S., Twining, P. & Tsai, C.-C. 2017. Research on ICT in K-12 schools – A review of experimental and survey-based studies in computers and education 2011 to 2015. Computers & Education 104, A1–A15. doi:10.1016/j.compedu.2016.09.006.

Põldoja, H., Väljataga, T., Laanpere, M. & Tammets, K. 2014. Web-based self- and peer-assessment of teachers' digital competencies. World Wide Web 17 (2), 255–269. doi:10.1007/s11280-012-0176-2.

Rahamat, R., Shah, P. M., Nor Puteh, S., Din, R. & Karim, A. A. 2011. End-users' involvement in the development of web-based learning resources for English literature. 3L: The Southeast Asian Journal of English Language Studies 17 (SPEC. ISSUE), 5–18.

Reeves, T. C. 2015. Educational design research: Signs of progress. Australasian Journal of Educational Technology 31 (5), 613–620.

Robertson, T. & Wagner, I. 2012. Ethics: engagement, representation and politics-in-action. In J. Simonsen & T. Robertson (Eds.) Routledge International Handbook of Participatory Design. Routledge, 64–85.

Rodrigo, R. & Ramírez, C. D. 2017. Balancing Institutional Demands with Effective Practice: A Lesson in Curricular and Professional Development. Technical Communication Quarterly 26 (3), 314–328. doi:10.1080/10572252.2017.1339529.

Rodríguez-Triana, M. J., Martínez-Monés, A., Asensio-Pérez, J. I. & Dimitriadis, Y. 2012. Towards a Monitoring-Aware Design Process for CSCL Scripts. doi:10.1007/978-3-642-33284-5.

Røkenes, F. M. & Krumsvik, R. J. 2016. Prepared to teach ESL with ICT? A study of digital competence in Norwegian teacher education. Computers & Education 97, 1–20. doi:10.1016/j.compedu.2016.02.014.

Saad-Sulonen, J., Eriksson, E., Halskov, K., Karasti, H. & Vines, J. 2018. Unfolding participation over time: temporal lenses in participatory design. CoDesign 14 (1), 4–16.

Salinas, Á., Nussbaum, M., Herrera, O., Solarte, M. & Aldunate, R. 2016. Factors affecting the adoption of information and communication technologies in teaching. Education and Information Technologies, 1–22. doi:10.1007/s10639-016-9540-7.

Sanders, E. B.-N. & Stappers, P. J. 2008. Co-creation and the new landscapes of design. CoDesign 4 (1), 5–18. doi:10.1080/15710880701875068.

Sanders, E. B.-N. & Stappers, P. J. 2014. From designing to co-designing to collective dreaming. Interactions 21 (6), 24–33.

Scherer, R., Siddiq, F. & Teo, T. 2015. Becoming more specific: Measuring and modeling teachers' perceived usefulness of ICT in the context of teaching and learning. Computers & Education 88, 202–214. doi:10.1016/j.compedu.2015.05.005.

Schuler, D. & Namioka, A. (Eds.) 1993. Participatory design: Principles and practices. New Jersey: Lawrence Erlbaum Associates, Inc., 319.

Selwyn, N., Henderson, M. & Chao, S.-H. 2017. The possibilities and limitations of applying 'open data' principles in schools. Cambridge Journal of Education 47 (2), 167–187. doi:10.1080/0305764X.2016.1143449.

Simonsen, J. & Robertson, T. (Eds.) 2013. Routledge International Handbook of Participatory Design. New York: Routledge, 295.

Siozos, P., Palaigeorgiou, G., Triantafyllakos, G. & Despotakis, T. 2009. Computer based testing using "digital ink": Participatory design of a Tablet PC based assessment application for secondary education. Computers & Education 52 (4), 811–819. doi:10.1016/j.compedu.2008.12.006.

Smith, R. C., Bossen, C. & Kanstrup, A. M. 2017. Participatory design in an era of participation. CoDesign 13 (2), 65–69. doi:10.1080/15710882.2017.1310466.

Smith, R. C., Iversen, O. S. & Hjorth, M. 2015. Design thinking for digital fabrication in education. International Journal of Child-Computer Interaction 5, 20–28.

Smith, R. C. & Iversen, O. S. 2018. Participatory design for sustainable social change. Design Studies, 1–28.

So, H.-J., Lossman, H., Lim, W.-Y. & Jacobson, M. J. 2009. Designing an online video based platform for teacher learning in Singapore. Australasian Journal of Educational Technology 25 (3), 440–457.

Somerville, M. M. & Collins, L. 2008. Collaborative design: a learner-centered library planning approach. The Electronic Library 26 (6), 803–820. doi:10.1108/02640470810921592.

Song, D. & Oh, E. Y. 2016. A Participatory Design Approach for a Mobile App-Based Personal Response System. Journal of Educational Technology Systems 44 (3), 346–361. doi:10.1177/0047239515618465.

Spinuzzi, C. 2002. A Scandinavian challenge, a US response. In Proceedings of the 20th annual international conference on Computer documentation - SIGDOC '02. New York, New York, USA: ACM Press, 208–215. doi:10.1145/584955.584986.

Spinuzzi, C. 2005. The methodology of participatory design. Technical Communication 52 (2), 163–174.

Steen, M. 2011. Tensions in human-centred design. CoDesign 7 (1), 45–60. doi:10.1080/15710882.2011.563314.

Steen, M. 2013. Virtues in Participatory Design: Cooperation, Curiosity, Creativity, Empowerment and Reflexivity. Science and Engineering Ethics 19 (3), 945–962. doi:10.1007/s11948-012-9380-9.

Stephen, M. L., Locke, S. M. & Bracey, G. L. 2014. Using a Participatory Design Approach to Create and Sustain an Innovative Technology-rich STEM Classroom - One School's Story. In Proceedings of the 6th International Conference on Computer Supported Education, Vol. 3. Center for Science, Technology, Engineering and Mathematics Research, Education, and Outreach, Southern Illinois University, Edwardsville, IL, United States: SCITEPRESS - Science and and Technology Publications, 30–38. doi:10.5220/0004849900300038.

Su, C., Chiu, C. & Wang, T. 2010. The development of SCORM-conformant learning content based on the learning cycle using participatory design. Journal of Computer Assisted Learning 26 (5), 392–406. doi:10.1111/j.1365-2729.2010.00355.x.

Suchman, L. 1988. Designing with the user: book review of Computers and democracy: a Scandinavian challenge, G. Bjerknes, P. Ehn, and M. Kyng, Eds. Gower Press, Brookfield, VT, 1987. ACM Transactions on Information Systems 6 (2), 173–183. doi:10.1145/45941.383895.

Tammets, K., Pata, K., Laanpere, M., Tomberg, V., Gašević, D. & Siadaty, M. 2011. Designing the competence-driven teacher accreditation. doi:10.1007/978-3-642-25813-8.

Tanhua-Piiroinen, E., Viteli, J., Syvänen, A., Vuorio, J., Hintikka, K. A. & Sairanen, H. 2016. Perusopetuksen oppimisympäristöjen digitalisaation nykytilanne ja opettajien valmiudet hyödyntää digitaalisia oppimisympäristöjä. Valtioneuvoston kanslia.

Tondeur, J., van Braak, J., Siddiq, F. & Scherer, R. 2016. Time for a new approach to prepare future teachers for educational technology use: Its meaning and measurement. Computers & Education 94, 134–150. doi:10.1016/j.compedu.2015.11.009.

Triantafyllakos, G., Palaigeorgiou, G. & Tsoukalas, I. A. 2011. Designing educational software with students through collaborative design games: The We!Design&Play framework. Computers & Education 56 (1), 227–242. doi:10.1016/j.compedu.2010.08.002.

Triantafyllou, E. & Timcenko, O. 2013. Developing digital technologies for university mathematics by applying participatory design methods. In 2013 24th EAEEIE Annual Conference (EAEEIE 2013). Dept. of Media Technology, Aalborg University Copenhagen, A.C. Meyers Vaenge 15, DK-2450 Copenhagen SV, Denmark: IEEE, 82–85. doi:10.1109/EAEEIE.2013.6576507.

Tuhkala, A. & Kärkkäinen, T. 2018. Using Slack for computer-mediated communication to support higher education students' peer interactions during Master's thesis seminar. Education and Information Technologies 23 (6), 2379–2397.

Tulinius, C., Brit, A., Nielsen, S., Hansen, L. J., Hermann, C., Vlasova, L. & Dalsted, R. 2012. Increasing the general level of academic capacity in general practice: Introducing mandatory research training for general practitioner trainees through a participatory research process. Quality in Primary Care 20 (1), 57–67.

Uluyol, Ç. & Şahin, S. 2016. Elementary school teachers' ICT use in the classroom and their motivators for using ICT. British Journal of Educational Technology 47 (1), 65–75. doi:10.1111/bjet.12220.

Vakil, S., McKinney de Royston, M., Suad Nasir, N. & Kirshner, B. 2016. Rethinking Race and Power in Design-Based Research: Reflections from the Field. Cognition and Instruction 34 (3), 194–209. doi:10.1080/07370008.2016.1169817.

Vines, J., Clarke, R., Light, A. & Wright, P. 2015. The beginnings, middles and endings of participatory research in HCI: An introduction to the special issue on 'perspectives on participation'. International Journal of Human-Computer Studies 74, 77–80. doi:10.1016/j.ijhcs.2014.11.002.

Vines, J., Clarke, R., Wright, P., McCarthy, J. & Olivier, P. 2013. Configuring participation: On How We Involve People In Design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13, Vol. 20. New York, New York, USA: ACM Press, 429.

Vrasidas, C. 2015. The rhetoric of reform and teachers' use of ICT. British Journal of Educational Technology 46 (2), 370–380. doi:10.1111/bjet.12149.

Wang, F. & Hannafin, M. J. 2005. Design-based research and technology-enhanced learning environments. Educational Technology Research and Development 53 (4), 5–23. doi:10.1007/BF02504682.

Wastiau, P., Blamire, R., Kearney, C., Quittre, V., Van de Gaer, E. & Monseur, C. 2013. The Use of ICT in Education: a survey of schools in Europe. European Journal of Education 48 (1), 11–27. doi:10.1111/ejed.12020.

Woolner, P., Clark, J., Hall, E., Tiplady, L., Thomas, U. & Wall, K. 2010. Pictures are necessary but not sufficient: Using a range of visual methods to engage users about school design. Learning Environments Research 13 (1), 1–22. doi:10.1007/s10984-009-9067-6.

Woolner, P., Hall, E., Wall, K. & Dennison, D. 2007. Getting together to improve the school environment: user consultation, participatory design and student voice. Improving Schools 10 (3), 233–248. doi:10.1177/1365480207077846.

Zainuddin, N. M. M., Zaman, H. B. & Ahmad, A. 2010. A Participatory Design in Developing Prototype an Augmented Reality Book for Deaf Students.

In 2010 Second International Conference on Computer Research and Development. Department of Information Science, Universiti Kebangsaan Malaysia, Bangi Selangor, Malaysia: IEEE, 400–404. doi:10.1109/ICCRD.2010.55.

Zheng, B., Warschauer, M., Lin, C.-H. & Chang, C. 2016. Learning in One-to-One Laptop Environments: A Meta-Analysis and Research Synthesis. Review of Educational Research 86 (4), 1052–1084.

Zimmerman, J., Forlizzi, J. & Evenson, S. 2007. Research through design as a method for interaction design research in HCI. In Proceedings of the SIGCHI conference on Human factors in computing systems - CHI ’07. New York, New York, USA: ACM Press, 493.

Zimmerman, J., Stolterman, E. & Forlizzi, J. 2010. An analysis and critique of Research through Design. In Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS ’10. New York, New York, USA: ACM Press, 310.

European Commission 2018. Communication on the Digital Education Action Plan. European Comission, 11.

Finnish National Board on Research Integrity 2018. Agreeing on authorship recommendation for research publications. The Finnish National Board on Research Integrity.

ORIGINAL PAPERS

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SEMI-AUTOMATIC LITERATURE MAPPING OF PARTICIPATORY DESIGN STUDIES 2006–2016

by

Tuhkala Ari, Kärkkäinen Tommi, and Nieminen Paavo 2018

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Semi-Automatic Literature Mapping of Participatory Design Studies 2006-2016

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ABSTRACT

The paper presents a process of semi-automatic literature mapping of a comprehensive set of participatory design studies between 2006-2016. The data of 2939 abstracts were collected from 14 academic search engines and databases. With the presented method, we were able to identify six education-related clusters of PD articles. Furthermore, we point out that the identified clusters cover the majority of education-related words in the whole data. This is the first attempt to systematically map the participatory design literature. We argue that by continuing our work, we can help to perceive a coherent structure in the body of PD research.

CCS CONCEPTS

• **Information systems → Clustering**; *Clustering and classification*; • **Human-centered computing → Participatory design**; • **Computing methodologies → Natural language processing**;

KEYWORDS

Systematic literature mapping, clustering, participatory design

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1 INTRODUCTION

The number of published scientific articles is increasing with high pace and new publication venues, such as journals, conferences, and open access archives, are emerging [19, 28]. To base research on existing body of knowledge, researchers use academic search engines and databases, such as ACM Digital Library. However, the problem is that there is no single search engine that would cover all different publication venues. Consequently, staying up to date with all published research has become arduous.

This problem accumulates in interdisciplinary fields, such as participatory design (PD). The domains, where PD is carried out, have extended from mere offices to schools, hospitals, and other contexts. Consequently, Participatory Design Conference proceedings represent only a fraction of all PD research and a vast amount of research is published in discipline-specific journals and conferences. Thus, researchers need to use several search engines and go through a large number of studies. This raises a question: could computational methods assist researchers in mapping previous knowledge and locating relevant literature?

This paper describes the process of a semi-automatic literature mapping and demonstrates the applicability of our method. First, we built a comprehensive set of all PD literature, that is published between 2006-2016, by systematically collecting studies from 14 different search engines and databases. Then, we conducted a semi-automatic mapping, similarly to the approach in Nieminen et al. [21], of this set of PD studies. We applied unsupervised learning to automatically find a division of topics and a thematic structure in a body of literature. Although, preprocessing the article dataset, determining the number of article clusters in recursive clustering, and interpreting the article clusters were done semi-automatically by the authors. To demonstrate the applicability of our method, we scrutinised the clusters to identify education related PD literature. In addition, we analysed the proportions of education-related words within these clusters. With our method, we managed to identify six education related clusters that covered the majority of education-related words.

This is the first attempt to systematically map PD research literature. For example, Halskov and Hansen [14, p.83] focused on Participatory Design Conference proceedings between 1990-2012. Nunes et al. [22, p.408] focused on IEEE and ACM databases. In line with Halskov and Hansen [14], we propose that systematic mapping of PD literature provides better understanding of where, how, and why PD has been carried out. This helps PD adjuncts to build more solid bases for their work by locating relevant studies and serving as a pre-stage for the actual literature review. For this, our study is an encouraging step. However, we remind that the quality, or relevance to a certain topic, of individual studies should not be based solely on the mapping. Instead, the method is useful when perceiving structure in a large amount of studies.

2 METHOD

2.1 Data Collection

The data collection took place in January 2017 and encompassed 14 databases: ACM Digital library, Bielefeld Academic Search Engine, EBSCOhost Research Databases, ERIC Institute of Education Sciences search, IEEE Xplore Digital library, JSTOR, ProQuest, SAGE Journals, ScienceDirect, Scopus, SpringerLink, Taylor and Francis

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Online, Wiley Online Library, and Thomson Reuters Web of Science. Criteria for database selection were the possibility to 1) export multiple references, 2) export references in Mendeley supported format, and 3) include abstracts in meta data. Thus, we excluded Google Scholar, Semantic Scholar, and CiteSeerX.

From the selected databases, we extracted references where title, abstract, or keywords contained keyword pair "participatory design", publication year was between 2006-2016, and publication type was either journal or conference article. We excluded book chapters, reports, reviews, theses, lectures, and patents, if it was possible in the search engine.

We combined the references in Mendeley to build a PD reference database. First, we removed the references that were obviously faulty, such as references with only empty meta-information. We inspected all references to ensure that the needed metadata (title, abstract, author, year, and publication venue) were included. If the reference had missing fields, we retrieved them manually. If it was not possible to retrieve the missing metadata with any of the search engines, we removed the reference. Some journals, such as MIT Design Issues, did not provide abstracts in meta data, but we could retrieve them from full texts.

We removed initial duplicates with the Mendeley's "Check for Duplicates" tool. We found that the tool cannot identify a duplicate, if an author's name is written with non-latin characters in one reference and with latin characters in another. We resolved these cases manually. After the duplicates were removed, the database consisted of 2939 articles.

2.2 Data processing

We exported the references as a single RIS file, which is a standard tag format by Research Information Systems. We exported the file to our preprocessor, which splits the titles and abstracts of each reference into words around whitespace boundaries and converts the words to lowercase. We removed the common English language stopwords by using the default English stopwords of the Natural Language Tool Kit (NLTK) corpus and stemmatised the words with NLTK Snowball stemmer [7]. The data contained 310013 non-stopword stems, of which 10194 were unique. Hereby, we refer to the word stem simply as *word*.

The top ten frequent words in data were: *design (12826), participatori (4177), use (3660), user (3468), develop (3280), process (2713), research (2525), particip (2330), paper (2142),* and *system (2073)*. As can be seen, manual addition of stopwords was needed to guide the algorithm to produce clusters based on the content words, not on the format. Thus, we removed the words from the query string (participatory design): *design (12826), participatori (4177), particip (2330), part (376), pd (844), redesign (100),* and *codesign (54)*. We also removed 1515 words based on the knowledge that they are typical research parlance and have no discriminative power, such as: *use (1480), develop (1282), paper (1251), process (1155), user (1130), studi (979), research (949), approach (892), base (848),* and *method (774)*. After adding the manual stopwords, the word matrix was ready for clustering the abstracts.

2.3 Data clustering

Clustering means unsupervised classification of observations into groups with a twofold aim: observations within a cluster should be similar to each other, and dissimilar to observations in other clusters [16]. There are various clustering methods and approaches, such as density-based, probabilistic, grid-based, and spectral clustering [1]. The most common clustering methods are hierarchical and prototype-based clustering, of which the basic form of hierarchical clustering is not scalable to the large volume of data because of the pairwise distance matrix requirement [32]. Moreover, many clustering algorithms, including the hierarchical clustering, can produce clusters of arbitrary shape in the data space, which is difficult or even impossible to interpret [25]. Thus, we avoided any dimension reduction technique (see [21]), and used a prototype-based clustering method with a global distance measure to identify groups of similar documents. When each cluster is characterised by a prototypical document, the cluster centroid, it is straightforward to determine a set of most typical documents of a cluster, closest to the centroid, for analysis and interpretation.

Well-known iterative relocation algorithms, most prominently the classical K-means [16, 20], approach clustering in two main steps: *i*) initial generation of K prototypes, *ii*) local search (refinement) of the initial prototypes. In general, initial prototypes should be well separated from each other without being outliers [16, 18]. Lately, the K-means++ algorithm [4], where the random initialisation is based on a density function favouring distinct prototypes, has become the most popular variant. However, because the search phase of these algorithms is locally exploitative, they need repeated restarts in initial prototype regeneration to address global exploration of the best clustering structure [15].

Each document is represented as a bag-of-words (BOW) vector with the number of occurrences of each stemmed word. Because the analysed documents arised from titles, abstracts, and keywords of the articles, we used the so-called *inverse document frequency (idf)* transformation [6] with the scaling function $\log(N/df)$, where N denotes the number of documents and df the overall word frequency. Even when such scaling changes the original data type of integers into real numbers, we still had a strictly discrete set of values with uniform quantization error [26]. Hence, we used the l_1/Cityblock distance, favorable compared in [11], as the distance function and to define the clustering error criterion. This means that we used as the actual clustering algorithm the K-medians++, which is an initialization strategy with the l_1-distance for the density function [4], and median as the document subset prototype within each cluster.

After few initial tests, we noticed the need for recursive application of the document clustering. This was suggested in [29] and successfully used for other application of clustering with c. 500 000 observations by [27]. We hypothesised that this is due to the different shapes and scales of document clusters, as illustrated in [5, Figure 5]. Similarly to the dimension reduction approach in [21], we re-applied the *idf*-scaling at each level of recursive clustering and removed the non-informative words with at most one occurrence within the analysed subset of documents. For the original document set, we had occurrences of 8672 words, which were then reduced to 4760 words of at least two occurrences. During the course of

Algorithm 1 Hierarchical application of prototype-based document clustering

Input: Set of documents with bag-of-words encoding.
Output: Set of prototypes and cluster labels for different refinement levels, through

1: Remove words with at most one instance and apply *idf*-scaling.
2: Cluster the current document set using K-medians++ with 1000 restarts for $K = 2, \ldots, 10$. Check CVAIs and select number of clusters according to the recommendation by one or more cluster indices.
3: Recursively recluster those document clusters which contain more than 300 documents.

recursive clustering, we fixed the threshold of 300 documents as the minimum size of a cluster, which was exposed to refinement.

In an unsupervised clustering scenario, the number of clusters (K) is unknown and needs to be estimated. The quality of the clustering result can be measured with the so-called Clustering Validation Indices (CVAI), which can be divided into three categories [32]: internal, external, and relative. Internal CVAIs, which do not utilise any external knowledge, typically measure the compactness and separation of clusters. To estimate the number of clusters, we used suggestions from the l_1-distance modified set of the best internal CVAIs, as identified in the tests in [15, 17]: K times the clustering error (kCE) [17], Wemmert-Ganciarsky (WG) [12, 13], Ray-Turi (RT) [24], Calinski-Harabasz (CH) [10], and Pakhira-Bandyopadhyay-Maulik (PBM) [23]. As an example, CH and RT suggested six clusters for the original document set.

The experiments were carried out in the Matlab-environment, by using the available *kmeans* clustering algorithm with the 'Cityblock' distance and 1000 repetitions. The overall document clustering method is summarised in Algorithm 1.

2.4 Duplicate identification

After the clustering, we assessed the BOW representation of the documents to identify possible duplicates. We studied the closest document match of the first 100 documents with the Euclidean distance by manually checking whether this was a duplicate. In this way, we detected the first three duplicates, along with their distances to the 'host' document. We used the maximum of these distances, 3.5, as the basis of threshold 3.6 when scanning through all 2939 documents. If we detected a document, of which the distance was less or equal than the threshold, we checked manually both the titles and the abstracts of such documents.

Even when we had used the Mendeley duplicate removal tool in data collection stage, we now identified 86 duplicates. Majority of duplicates occurred because two different search engines had exported titles in a slightly different form. Another source of difference, that was not detected by Mendeley but revealed here, was that the title or abstract of the same article was written in two different languages. However, and slightly alarmingly, we identified cases where the same abstract, or almost the same, was used in a different article, such as: [2] and [3], [8] and [9], [30] and [31].

3 FINDINGS

Figure 1 shows an overview of the total number of 53 clusters and 49 unique articles on 21 refinement levels. The clusters are marked as boxes, where the number represents the size of a cluster (number of articles). The clusters containing more than 300 articles, and thus chosen for re-clustering, are emphasised with bold lines. Unique articles, that were not assigned to any cluster, are emphasised with dotted lines. The clusters that are vertically aligned belong to the same refinement level. For example, clustering of the original document set provided six clusters of sizes 141, 123, 1984, 125, 103, and 377, of which the third and the sixth were reclustered.

3.1 Education-related clusters

Interpretation of document clusters was based on interactive expert analysis of the most frequent words and the most representative documents. First we assessed the 20 most common words of a cluster, how much of the total occurrences in the whole document set they cover (in percentages). Then, similarly to the BOW duplicate detection, we scanned through the titles, abstracts, and keywords of ten documents in the cluster, closest to the cluster prototype. In this way, out of the whole set, we identified six clusters related to the joint theme of PD in education (Table 1).

3.2 Word portions of education-related clusters

The preprocessor provided a list of all words in the data, sorted from the highest frequency to the lowest. From this list, we selected education related words with the frequency of 30 or higher. Table 2 presents these words (Word), word frequency in the whole data (Freq), and number of articles that include the word at least once (AF). Then, the table displays the word portions of all six education related clusters. The number shows how many percentages the cluster covers from the total word frequency. Thus, the final column (Total) shows how many percents the six education related clusters cover from total frequency all together.

4 DISCUSSION

Due to the restricted space of a short paper, this study concentrated on demonstrating the semi-automatic clustering method for the systematic literature mapping of PD studies. In the future, we provide more detailed analysis of the clusters and the most representative articles. Furthermore, we analyse articles that the algorithm could not assign to any cluster, because they may represent some exceptional studies in PD field. In addition, we provide an access to the collected literature by implementing a web interface that uses Mendeley API [1].

The main challenge of the systematic mapping was that data collection stage took a lot of manual work. This was due to the faced usability problems in the used academic search engines. For illustration: ACM Digital Library did not provide abstracts when exporting multiple references, so we copied them manually. In EBSCOhost, references needed to be moved to a folder (50 at a time) and downloaded, with a limit of 150 references at a time. In JSTOR, references needed to be selected by clicking a checkbox, one by one, and then exported. To overcome this kind of defiencies, academic search engines should improve and standardise their database meta-information fields, search protocols, and exporting features.

[1] Mendeley API: http://dev.mendeley.com, retrieved 15.1.2018

Figure 1: Cluster map

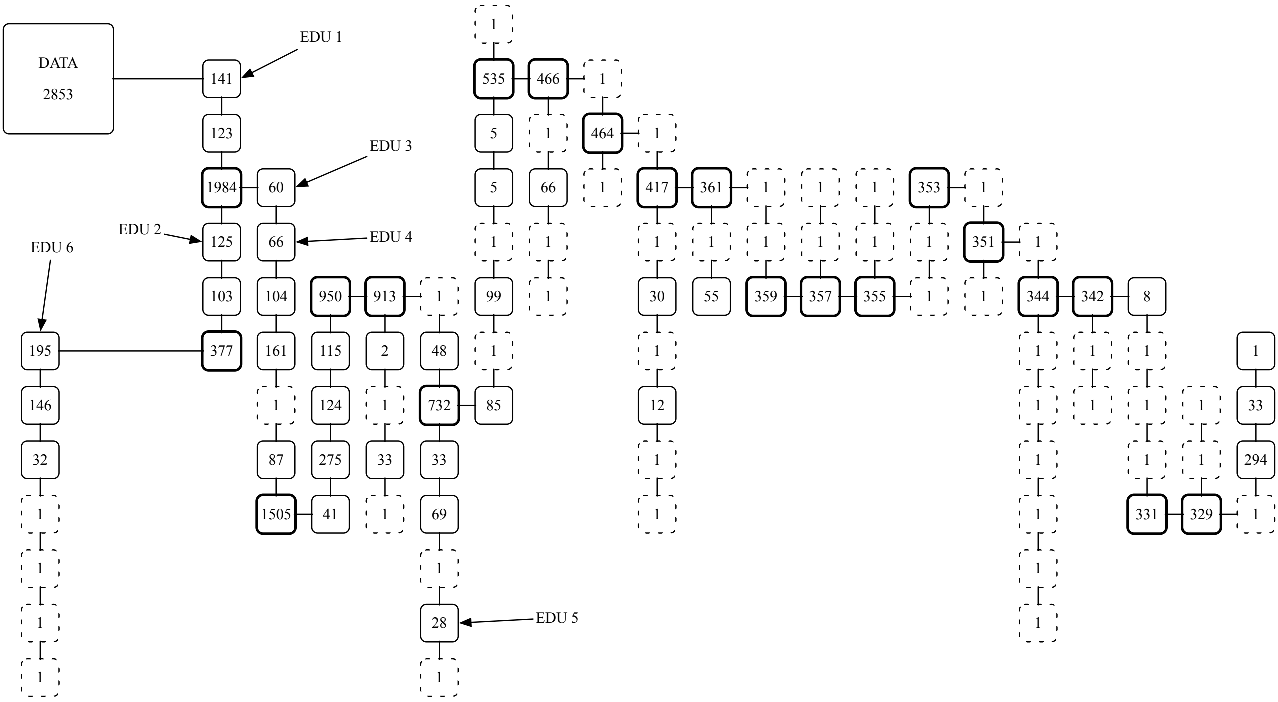

Table 1: PD in education clusters

Cluster	Articles	Journal / conference	Name
EDU 1	141	79 / 62	PD in learning, learning technology including edugames, and learning environment design
EDU 2	125	59 / 66	Designing with children and for children (also with special needs)
EDU 3	60	29 / 31	Game design and gaming in design
EDU 4	66	38 / 28	Teaching PD and PD in learning design
EDU 5	28	18 / 10	PD with students and for educational activities
EDU 6	195	100 / 95	Educational and assistive technology design

Table 2: Word portions of the PD in education clusters

Word	Freq	AF	EDU 1	EDU 2	EDU 3	EDU 4	EDU 5	EDU 6	Total
learn	1372	590	55.4	5.4	1.7	4.3	0.6	4.2	71.6
educ	814	392	16.8	5.4	3.3	13.2	9.0	12.4	60.1
student	791	265	24.9	0.8	1.8	41.3	1.7	5.1	75.6
school	418	184	16.3	15.3	4.1	10.5	4.8	8.2	59.2
teacher	390	151	38.8	7.1	4.5	11.6	2.4	9.2	73.6
teach	172	101	27.9	1.2	4.2	19.4	1.2	6.1	60.0
learner	138	70	56.3	3.7	2.2	5.2	1.5	4.4	73.3
classroom	115	55	36.9	5.8	1.0	12.6	8.7	6.8	71.8
instruc	120	64	32.2	2.5	3.4	11.9	2.5	2.5	55.0
pedagog	45	33	42.2	13.3	4.4	8.9	0.0	15.6	84.4
curriculum	42	30	26.2	0.0	7.1	11.9	4.8	0.0	50.0
pedagogi	30	24	42.9	3.6	0.0	3.6	0.0	0.0	50.1
Mean	370.6	163.3	34.7	5.4	3.2	12.9	3.1	6.2	65.4

REFERENCES

[1] Charu C Aggarwal and Chandan K Reddy. 2013. *Data clustering: algorithms and applications*. CRC press.

[2] Meghan Allen, Joanna McGrenere, and Barbara Purves. 2007. The Design and Field Evaluation of PhotoTalk: A Digital Image Communication Application for People. In *Proceedings of the 9th International ACM SIGACCESS Conference on Computers and Accessibility (Assets '07)*. ACM, New York, NY, USA, 187–194. https://doi.org/10.1145/1296843.1296876

[3] Meghan Allen, Joanna McGrenere, and Barbara Purves. 2008. The Field Evaluation of a Mobile Digital Image Communication Application Designed for People with Aphasia. *ACM Trans. Access. Comput.* 1, 1, Article 5 (May 2008), 26 pages. https://doi.org/10.1145/1361203.1361208

[4] David Arthur and Sergei Vassilvitskii. 2007. K-means++: The advantages of careful seeding. In *Proceedings of the eighteenth annual ACM-SIAM symposium on Discrete algorithms*. Society for Industrial and Applied Mathematics, 1027–1035.

[5] Sami Äyrämö. 2006. *Knowledge Mining Using Robust Clustering*. Jyväskylä Studies in Computing, Vol. 63. University of Jyväskylä.

[6] Ricardo Baeza-Yates, Berthier Ribeiro-Neto, et al. 1999. *Modern information retrieval*. Vol. 463. ACM press New York.

[7] Steven Bird, Ewan Klein, and Edward Loper. 2009. *Natural language processing with Python: analyzing text with the natural language toolkit*. O'Reilly Media, Inc.

[8] Tone Bratteteig and Ina Wagner. 2010. Spaces for Participatory Creativity. In *Proceedings of the 11th Biennial Participatory Design Conference (PDC '10)*. ACM, New York, NY, USA, 51–60. https://doi.org/10.1145/1900441.1900449

[9] Tone Bratteteig and Ina Wagner. 2012. Spaces for participatory creativity. *CoDesign* 8, 2-3 (2012), 105–126. https://doi.org/10.1080/15710882.2012.672576

[10] Tadeusz Caliński and Jerzy Harabasz. 1974. A dendrite method for cluster analysis. *Communications in Statistics-theory and Methods* 3, 1 (1974), 1–27.

[11] John Collins and Kazunori Okada. 2012. A Comparative Study of Similarity Measures for Content-Based Medical Image Retrieval. In *CLEF (Online Working Notes/Labs/Workshop)*.

[12] Bernard Desgraupes. 2013. Clustering indices. *University of Paris Ouest-Lab Modal'X* 1 (2013), 34.

[13] Germain Forestier, Pierre Gançarski, and Cédric Wemmert. 2010. Collaborative clustering with background knowledge. *Data & Knowledge Engineering* 69, 2 (2010), 211–228.

[14] Kim Halskov and Nicolai Brodersen Hansen. 2015. The diversity of participatory design research practice at PDC 2002–2012. *International Journal of Human-Computer Studies* 74 (feb 2015), 81–92. https://doi.org/10.1016/j.ijhcs.2014.09.003

[15] Joonas Hämäläinen, Susanne Jauhiainen, and Tommi Kärkkäinen. 2017. Comparison of Internal Clustering Validation Indices for Prototype-Based Clustering. *Algorithms* 10, 3 (2017), 1–14.

[16] Anil K. Jain. 2010. Data clustering: 50 years beyond K-means. *Pattern Recognition Letters* 31, 8 (2010), 651–666.

[17] Susanne Jauhiainen and Tommi Kärkkäinen. 2017. A Simple Cluster Validation Index with Maximal Coverage. In *Proceedings of the European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning - ESAINN 2017*. 293–298.

[18] Shehroz S Khan and Amir Ahmad. 2013. Cluster center initialization algorithm for K-modes clustering. *Expert Systems with Applications* 40, 18 (2013), 7444–7456.

[19] Peder Olesen Larsen and Markus von Ins. 2010. The rate of growth in scientific publication and the decline in coverage provided by Science Citation Index. *Scientometrics* 84, 3 (sep 2010), 575–603. https://doi.org/10.1007/s11192-010-0202-z

[20] S. Lloyd. 1982. Least squares quantization in PCM. *IEEE Transactions on Information Theory* 28, 2 (1982), 129–137.

[21] Paavo Nieminen, Ilkka Pölönen, and Tuomo Sipola. 2013. Research literature clustering using diffusion maps. *Journal of Informetrics* 7, 4 (oct 2013), 874–886. https://doi.org/10.1016/j.joi.2013.08.004

[22] Eunice P. S. Nunes, Alessandro R. Luz, Eduardo M. Lemos, and Clodoaldo Nunes. 2016. *Approaches of Participatory Design in the Design Process of a Serious Game to Assist in the Learning of Hospitalized Children*. Springer International Publishing, Cham, 406–416. https://doi.org/10.1007/978-3-319-39513-5_38

[23] Malay K Pakhira, Sanghamitra Bandyopadhyay, and Ujjwal Maulik. 2004. Validity index for crisp and fuzzy clusters. *Pattern recognition* 37, 3 (2004), 487–501.

[24] Siddheswar Ray and Rose H Turi. 1999. Determination of number of clusters in k-means clustering and application in colour image segmentation. In *Proceedings of the 4th international conference on advances in pattern recognition and digital techniques*. Calcutta, India, 137–143.

[25] Mirka Saarela, Joonas Hämäläinen, and Tommi Kärkkäinen. 2017. Feature Ranking of Large, Robust, and Weighted Clustering Result. In *Pacific-Asia Conference on Knowledge Discovery and Data Mining*. Springer, 96–109.

[26] Mirka Saarela and Tommi Kärkkäinen. 2015. Analysing Student Performance using Sparse Data of Core Bachelor Courses. *JEDM-Journal of Educational Data Mining* 7, 1 (2015), 3–32. http://www.educationaldatamining.org/JEDM/index.php/JEDM/article/view/JEDM056

[27] Mirka Saarela and Tommi Kärkkäinen. 2015. Do country stereotypes exist in educational data? A clustering approach for large, sparse, and weighted data.. In *Proceedings of the 8th International Conference on Educational Data Mining (EDM 2015)*. 156–163.

[28] Richard Van Noorden. 2014. Global scientific output doubles every nine years. (2014).

[29] P. Wartiainen and T. Kärkkäinen. 2015. Hierarchical, prototype-based clustering of multiple time series with missing values. In *Proceedings of the European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning - ESAINN 2015*. 95–100.

[30] Y. Yu and Z. Liu. 2006. Integrated scenario-based design method for interactive online teaching system. In *2006 International Conference on Computational Inteligence for Modelling Control and Automation and International Conference on Intelligent Agents Web Technologies and International Commerce (CIMCA'06)*. 153–153. https://doi.org/10.1109/CIMCA.2006.128

[31] Y. Yu and Z. Liu. 2006. Research on a user-centered design method for interactive online teaching system. In *2006 International Conference on Communication Technology*. 1–4. https://doi.org/10.1109/ICCT.2006.341739

[32] Mohammed J Zaki and Wagner Meira Jr. 2014. *Data Mining and Analysis: Fundamental Concepts and Algorithms*. Cambridge University Press.

PII

INVOLVING TEACHERS IN PARTICIPATORY DESIGN: SYSTEMATIC MAPPING OF STUDIES BETWEEN 2007 AND 2017

by

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Involving Teachers in Participatory Design: Systematic Mapping of Studies between 2007 and 2017

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Abstract

Participatory design has been proposed as a potential approach to involve teachers in designing learning innovations. This study examines this topic by conducting a systematic literature mapping of participatory design studies between 2007 and 2017 that have involved teachers. A representative set of studies was collected from 14 search engines and databases. The studies were mapped into specific categories and synthesised to produce an overview of the current research. The main categories were environments, practices, and technologies. The studies in the environments category involved teachers in designing physical buildings, as well as technologies integrated into the environment. The practices category considered professional communities, instructional planning, and professional development programmes. The technologies category considered assessment and monitoring tools, educational games, learning and teaching applications, security and safety technology, and technology for special needs. This mapping serves as a solid basis for future research on involving teachers in participatory design.

Keywords: participatory design, systematic literature mapping, teachers, education

1. Introduction

Realising the possible benefits of educational innovations relies greatly on teachers (OECD, 2015; European Commission, 2018). However, while teacher's role is acknowledged as implementer, teachers are often denied the opportunity to influence what is being implemented (Cviko et al., 2014; Kyza and Nicolaidou, 2017). For example, when regarding technological innovations in education, a systematic literature review in *Computers and Education* shows that of 352 studies, only 30 percent involved teachers, and only 24 percent involved stakeholders in co-designing technology, whether they were teachers or not (Pérez-Sanagustín et al., 2017, p. A11).

A recent book, *Participatory Design for Learning*, presented participatory design (PD) as an untapped resource for improving the development, implementation, and sustainability of learning innovations through direct input from educational stakeholders (DiSalvo et al., 2017). PD is a well-known approach that advocates for involving stakeholders as decision-makers in design, instead of mere informants, through collaboration and mutual learning (Kensing and Blomberg, 1998; Simonsen and Robertson, 2013; Halskov and Hansen, 2015; Frauenberger et al., 2015). PD is most familiar in the field of Human–Computer Interaction, but it has been found appealing also in educational context. This has resulted in special issues about PD in *Instructional Science* (Könings et al., 2014), *Cognition and Instruction* (Bang and Vossoughi, 2016), and *European Journal of Education* (Könings and McKenney, 2017).

Previous investigations about PD in education have focused on students, especially when developing technology for students with special needs (Druin, 2002; Iversen and Dindler, 2013; Benton and Johnson, 2015). While there are studies that focus on teachers, the findings are scattered across several publication

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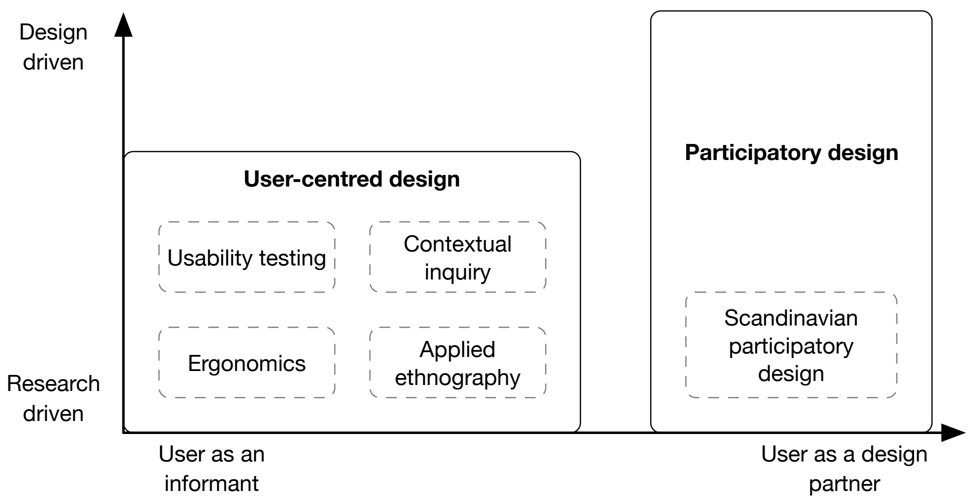
venues and from different fields. Therefore, this study examined: **For what purpose have PD studies involved teachers?** This question was answered by conducting a systematic mapping of all PD studies between 2007 and 2017 that have involved teachers as main stakeholders. A comprehensive set of PD studies was collected from 14 academic search engines and databases [blinded reference]. The studies were scrutinised with rigorous inclusion and exclusion criteria and tabulated into specific categories (Kitchenham and Charters, 2007; Kitchenham et al., 2010). These categories were synthesised to produce an overview of the current body of knowledge regarding teacher involvement in PD. Research purposes, methods, and main findings of individual studies are included in the appendix.

2. Participatory design

There are many design-related research paradigms. Well-known examples, especially in the educational context, include design-based research (Wang and Hannafin, 2005), educational design research (Reeves, 2015), and human-centred design or user-centred design (Iivari and Iivari, 2006; Steen, 2011). Common to these paradigms is to consider design, practice, and research together: design as envisioning new objects and representing them by drawing, modifying tangible materials, or utilising digital tools; practice as solving concrete problems through iterative cycles of design, development, enactment, and analysis; and research as collecting and analysing data to examine the outcomes.

PD is positioned here in relation to the framework of design paradigms that has been defined by Sanders and Stappers (2008). This framework is presented in Figure 1. The horizontal axis has two edges: *user as an informant* and *user as a design partner*. It depicts two different ways to configure user participation in design. In the former, users are investigated – how they perceive and react to different materials, forms, and stimuli – to modify the functionality of the designed object. In the latter, users are active agents who influence and make decisions in design. The edges on the vertical axis are *design driven* and *research driven*. This depicts which outcome is the more predominant purpose of user participation: design objects or construct knowledge. For example, involving users for purely artistic purposes would be design-dominant, and involving users only for data collection purposes would be research-dominant.

Figure 1: Landscape of design paradigms (adapted from Sanders and Stappers, 2008, p. 6).



User-centred design is a broad category for approaches in which the user is the object of investigation. In *usability testing*, users test new designs and the objects are modified based on these findings. This can also be based on existing knowledge, such as when designing furniture based on human anatomy, as in *ergonomics*. In *contextual inquiry*, design is informed by interviewing users about use practices, wherein *applied ethnography* the users are observed. As such, all these approaches are research-driven. For example, it is difficult to see how contextual inquiry could be separated from the user interviews without losing its very purpose. Similarly, PD can be understood as a broad category. The reason for comparing these two categories is to highlight the differences: while the focus in user-centered design is to investigate users to develop new solutions, the focus in PD is to create a space where users, designers, and researchers explore the problem and envision the solutions together (Leong and Iversen, 2015).

Scandinavian participatory design can be characterised as an action-research inspired approach, which means that both design and research are driven by local accountability: to support the local stakeholders instead of just producing objects and knowledge (see Simonsen and Robertson, 2013, p. 44). This approach was rooted in the workplace democracy movement in Scandinavia that emerged in the late 1960s and 1970s (Bjerknes and Bratteteig, 1995; Simonsen and Robertson, 2013; Bødker and Kyng, 2018). The movement addressed concerns over employees' opportunities to influence how, and with what implications, computer systems were introduced at their workplaces (Beck, 2002). The foundations were built in early action research projects that demanded more democratic working conditions and developed new technology, work practices, and design methods (Gregory, 2003; Iversen et al., 2012; Bødker and Kyng, 2018).

Nowadays, PD researchers and practitioners form an established and multidisciplinary community that is more or less committed to the ideals of the Scandinavian tradition (Vines et al., 2015). These ideals are familiar from a book called *Computers and Democracy: a Scandinavian challenge* (Bjerknes et al., 1987), which was described as a genuinely human-centered alternative to technology design (Suchman, 1988): First, design addresses the contradiction between tradition and transcendence – what is and what could be – so design can either support old practices, values, and power structures or aim to change them (Ehn, 1988). Second, people who are affected by design should be involved in making decisions about it (Greenbaum, 1993; Simonsen and Robertson, 2013). Topics like democratic decision-making and empowering marginalised people are still in current debate, especially in the community's main venue: the biannual Participatory Design Conference. At the same time, the pragmatic side of PD, that is developing techniques for involving stakeholders, has pervaded other design approaches as well (Bødker et al., 2000; Spinuzzi, 2002; Bødker and Kyng, 2018). This has led to an intensive discussion of what are, or should be, the contemporary characteristics of PD (Halskov and Hansen, 2015; Smith et al., 2017; Bødker and Kyng, 2018; Pilemalm, 2018).

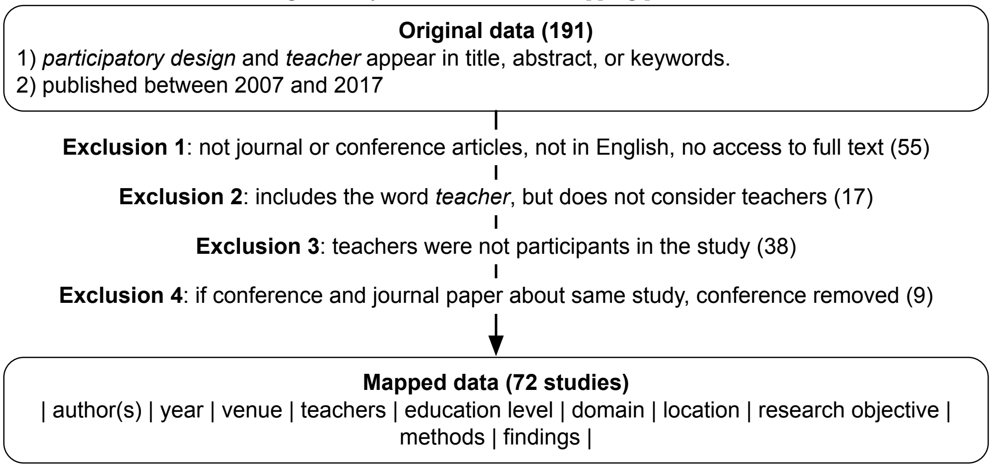
3. Systematic mapping process

Data collection took place over 14 search engines and databases to gather a wide sample of PD literature: ACM Digital library, Bielefeld Academic Search Engine, EBSCOhost Research Databases, ERIC Institute of Education Sciences search, IEEE Xplore Digital library, JSTOR, ProQuest, SAGE Journals, ScienceDirect, Scopus, SpringerLink, Taylor and Francis Online, Wiley Online Library, and Thomson Reuters Web of Science. Criteria for database selection were the possibility to 1) export multiple references and 2) export references in Mendeley supported format (RIS, Bibtex, Endnote XML, or Zotero). Thus, Google Scholar, Semantic Scholar, and CiteSeerX were excluded.

References where *participatory design* appeared in title, abstract, or keywords, and which were published between 2007 and 2017 were collected. The references from different search engines were imported to the Mendeley reference management tool to build a single reference database (2943 articles). Because two references could have different meta-information and still point to the same source, the duplicates were removed by using the duplicate identification tool. From the reference database, the references that included the word *teacher* either in title, abstract, or keywords were extracted. In total, 191 references included both *teacher* and *participatory design*.

The data refinement process is illustrated in Figure 2. In the first exclusion stage, the references were screened and those not published in a journal or conference, written in English, or where there was no access to full text in any of the 14 databases were removed (55 articles). The excluded references consisted of workshop descriptions, research proposals, posters, extended abstracts, introductions to special issues, and editorial notes.

Figure 2: Systematic literature mapping protocol.



Before the second exclusion stage, full text articles for each remaining reference were downloaded. Articles that included the words *participatory design* but defined the study as action research, user-centred design, or another research approach were eliminated for being beyond the scope of the present study (17 articles).

In the third exclusion stage, the articles that did not involve teachers as participants were removed (37 articles). For example, Hussain (2010) stated that *valuable user perspectives are lost if only information from adult carers such as* ***teachers*** *and parents are included in the design process* but did not consider teachers any further. Studies that did not define the participants in detail, but obviously considered teachers, were included. The final exclusion stage (9 articles) removed conference articles where the same research was reported in a journal article.

The following basic information was then extracted to an Excel sheet after reading all the articles: author(s), year, venue, participants, amount of teachers as participants, other stakeholders, education level, and geographical location. The articles were scrutinised in detail and mapped according to the research objectives, methods, and main findings. These results were analysed to assign the articles into three categories: environments, practices, and technologies. These categories were further refined into sub-categories.

4. Results

A summary of the studies involving teachers in PD is presented in Table 1. Most of the studies were published in journals (51). The studies considered several education levels: pre-primary, primary, secondary, and higher education. Moreover, seven studies were about PD in teacher education, and six investigated PD in more than one education level. Most of the studies were small-scale investigations such as case studies, with no more than five teacher participants. Seven large-scale studies consulted 20 or more teachers. However, some studies did not specify the exact number of teacher participants. Over half the studies were conducted in the United Kingdom, Netherlands, United States, Australia, and Finland, and five studies covered more than one geographical location.

Environments

Table 2 presents the studies related to learning environments. In the largest category, *School buildings*, teachers were involved in envisioning a new school concept or re-design of an existing concept (Burke and Könings, 2016; Koutamanis et al., 2017; Könings et al., 2017; van Merriënboer et al., 2017; Woolner et al., 2007, 2010). These studies approached the school building as a whole, including furniture, (technological) equipment, materials, and structures, whereas two of the studies focused on specific facilities: the university

Table 1: Summary of participatory design studies involving teachers ($n = 72$).

Venue	**Education level**	**Number of teachers**	**Location**
Journal: 51	Pre-primary: 2	Not defined: 22	United Kingdom: 16
Conference: 21	Primary: 22	1 – 5: 25	Netherlands: 10
	Secondary: 19	6 – 10: 9	United States: 7
	Higher: 16	11 – 20: 9	Australia: 5
	Teacher education: 7	Over 20: 7	Finland: 4
	Several levels: 6		Rest of Europe: 16
			Asia: 6
			Rest of the world: 3
			Multiple locations: 5

cafeteria (Lundström et al., 2016), and library learning commons (Somerville and Collins, 2008). In the second category, *Technology-enhanced learning spaces*, the studies focused not only on the physical space but also on how technology is integrated into the learning environment.

Table 2: Teachers in participatory design of environments ($n = 15$).

Category	Articles
School buildings	Burke and Könings (2016), Koutamanis et al. (2017), Könings et al. (2017), Lundström et al. (2016), van Merriënboer et al. (2017), Somerville and Collins (2008), Woolner et al. (2007), Woolner et al. (2010)
Technology-enhanced learning spaces	Bossen et al. (2010), Casanova and Mitchell (2017), Cober et al. (2015), Joyce et al. (2014), Kreitmayer et al. (2013), Otero et al. (2013), Stephen et al. (2014)

Regarding the studies in the *School buildings* category, Burke and Könings (2016) examined how a school's history inspired the participants' design imagination. They present an example from the Netherlands, De Werkplaats, a school that was re-designed according to the educational thinking of Kees Boeke. They point out how a historical narrative can be utilised as a positive agent for change, but also that previous traditions from more conservative schools can limit and hinder the potential for design innovations.

Two other studies took place at De Werkplaats. As reported by Koutamanis et al. (2017), visual information technology (Building Information Model) was utilised as a collaborative tool during the building's life-cycle. The tool served as a knowledge repository and a communication service, which enabled the participants to engage in decision-making. van Merriënboer et al. (2017), in turn, addressed the relationship between pedagogy and physical spaces. They framed a three-stage design process: specifying the pedagogy, aligning the chosen pedagogy with seating arrangements and physical learning spaces, and realising the school building. They found PD especially beneficial when teachers' pedagogical needs and architects' non-pedagogical needs (resources, cost-effectiveness) contradicted (Woolner et al., 2007). van Merriënboer et al. (2017) conclude that the PD of school buildings is not about the building *per se*, but negotiating a shared pedagogical vision and establishing a commitment to this vision.

Two methodological contributions deserve to be highlighted. Woolner et al. (2010) accounted for using visual tools, such as photo elicitation, diamond mapping, and map-based activities, to gather perceptions of various participants and to improve the learning environment. They concluded that the visual methods produced rich understandings of the current school environment and enabled the triangulation of participants' different perceptions. The second study developed an interdisciplinary model of practice for participatory building design (Könings et al., 2017). The model integrates an action research cycle, stakeholder analysis model, ladder of participation tool, and participation matrix to address the complexity of involving several different stakeholder roles.

In the *Technology-enhanced learning spaces* category, three studies developed technologies to be integrated into classrooms: an Internet of Things ecosystem (Joyce et al., 2014), UniPad application (Kreitmayer et al., 2013), and digital displays (Otero et al., 2013). Two studies involved teachers in designing new learning environments where technology plays a major part. Casanova and Mitchell (2017) provided participants with two provocative design space concepts, which were then re-designed. This process resulted in rich data about how the participants conceptualised the learning spaces and the value of technology. Similarly, Stephen et al. (2014) involved teachers and students to design technology-rich classrooms as *community spaces* that are owned and maintained together.

Two studies are described in detail because they pay specific attention to teachers' participation. Bossen et al. (2010) accounted for a large PD project, *iSchool*, which was about envisioning new learning spaces and opportunities of pervasive technology. They interviewed the teachers three years after the project ended and examined what they gained from the project. According to the teachers, the most satisfying experiences were: reflecting with professionals from other backgrounds, the enthusiasm of the students towards technology, and gaining experience from using modern technology. Moreover, the teachers expressed four types of gains: opportunity to reflect on teaching methods, to develop skills and understandings about technology, to have leverage to influence technology-related decisions, and to advance their own interest in technology.

Cober et al. (2015) analysed teacher engagement in two case studies and investigated what supports teacher participation. The teachers engaged in: theory-driven discussions with researchers and developers to ground design work and understand each others' perspectives; design partnerships by providing input, guidance, and ideas; reflecting on the innovations from a pedagogical perspective and evaluating the potential impact for students; and adjusting implementation enactments. Regarding the conditions supporting the teachers, the authors highlighted a combination of highly facilitated conditions and flexibility, an atmosphere of trust and partnership, and designing with contextual knowledge about the physical environment, students, and potential technologies.

Practices

The studies in the *Learning practices* category were about establishing professional communities, intstructional design, and professional development programmes (Table 3).

Table 3: Teachers in participatory design of practices ($n = 29$).

Category	Articles
Communities	Booker and Goldman (2016), Duell et al. (2014), Farooq et al. (2007), Ishimaru and Takahashi (2017), Karimi et al. (2017), Pollock and Amaechi (2013), Selwyn et al. (2017), Tammets et al. (2011), Vakil et al. (2016)
Instructional design	Anderson and Östlund (2017), Barbera et al. (2017), Gros and López (2016), Harrison et al. (2017), Janssen et al. (2017), Kuure et al. (2016), Könings et al. (2011), Könings et al. (2010), Könings et al. (2007b, A), Könings et al. (2007a, B), Prins et al. (2016)
Professional development	Al-Eraky et al. (2015), Goeze et al. (2014), Janssen et al. (2014), Kyza and Georgiou (2014), Kyza and Nicolaidou (2017), Põldoja et al. (2014), Rodrigo and Ramírez (2017), So et al. (2009), Tulinius et al. (2012)

In the *Professional communities* category, two studies examined online communities. Duell et al. (2014) established a yearly ambassador programme for introducing design thinking as a general competency in K-12 education in Australia. In this study, PD was undertaken to create an online design education platform and to increase teachers' capacity to teach creativity and design. Farooq et al. (2007) developed an online environment for a diverse community of distributed education professionals. The project drew on PD and included four design interventions. The study proposed that the interventions were successful because the community members developed ownership over the online environment and kept using it for long-term professional development and social networking. Karimi et al. (2017) organised a *hackathon* workshop for teachers, where the teachers experimented with technology and designed learning activities. Because the teachers faced challenges implementing the digital technology projects, it provided an honest experience of exploring novel technologies and demystifying some aspects of technical practices.

The other studies in this sub-category were about empowering local communities. Booker and Goldman (2016) examined PD as an approach to tackle math fears in families by restoring epistemic authority. Pollock and Amaechi (2013) explored how texting supports rapid and individualised communication with vulnerable youth. Selwyn et al. (2017) explored the possibilities of making existing school data available in digital form for teachers, students, and administrators. This study revealed technical, informational, organisational, and social issues in democratising data engagement within school settings. Tammets et al. (2011) examined a teacher accreditation programme that requires the teachers to be involved in community of practices, collaborative learning, and knowledge building. Finally, Vakil et al. (2016) used the notion of politicised trust to analyse how political and racial solidarity was established, contested, and negotiated throughout two PD projects.

The *Instructional design* category consists of studies about designing learning practices and curricula. Most of the studies were conducted by the same researchers from the Netherlands. Könings et al. (2007b, A) aimed to reduce discrepancies between students' and teachers' perceptions on appropriate learning environments and to collaboratively design these environments. Könings et al. (in 2007a, B) expanded this work by focusing on teachers. In two other studies (Könings et al., 2010, 2011), the authors invited students to collaborate with teachers. Both the teachers and students found PD appealing in this context, but with several challenges: PD takes too much time, students underestimate their capability to decide educational issues, teachers doubt students' willingness to take part in PD, and PD outcomes were perceived positively by the students involved but not by the rest of the class.

Janssen et al. (2017) defined *participatory educational design* and conducted a study with three aims: to view classroom teaching as bounded rational design, develop a tool that supports participants in mapping and sharing their goals, and develop another tool that helps participants to explore practical and effective possibilities for designing learning environments. This study demonstrated the use of tools for improving the quality and usability of learning environments and stated that even participants with similar backgrounds benefited from learning about each others' practices and goals.

The remaining studies in this sub-category considered a variety of topics. Barbera et al. (2017) developed learning scenarios to identify *moments of change* and describe causes and agents that motivate these changes. Gros and López (2016) examined the Learning Centric Ecology of Resources model to facilitate co-design processes. Two studies considered assessment in teaching: Harrison et al. (2017) explored how to redesign a summative assessment culture that takes into account students' post-assessment feedback, and Anderson and Östlund (2017) considered assessment practices of students who attend special schools. Janssen et al. (2014) developed a PD-based teacher training trajectory for guided discovery learning (GDL) lessons in biology. Accordingly, the teachers were willing and capable of implementing GDL, utilised the heuristics that were developed by experienced teachers, and valued GDL at a higher level than regular lessons. Kuure et al. (2016) supported English teachers in a Finnish university to become designers of language learning with new technologies, and Prins et al. (2016) developed an instructional framework that provided educational designers with a set of prescriptive guidelines for transforming authentic modelling practices.

Two studies in the *Professional development* category were about improving professional development through PD. Kyza and Georgiou (2014) examined PD for promoting teachers' sense of ownership towards inquiry-based learning modules. Accordingly, the teachers perceived PD as a collaborative and supportive framework that enables the exchange of different perspectives, encourages critical constructivism, and facilitates new teaching methods and technologies. Conversely, the time-consuming nature of PD, communication problems, and participants' unequal contributions were identified as the main disadvantages. Despite this, all teachers preferred designing the teaching module over using pre-made modules. Kyza and Nicolaidou (2017) conclude that iterative design facilitated teachers' professional development because it enabled teachers to reflect on inquiry learning and teaching.

The remaining studies in this category were about training programmes. Al-Eraky et al. (2015) involved teachers in designing a faculty development programme for teaching professionalism in medical education, Rodrigo and Ramírez (2017) developed a master course for online teaching, and Tulinius et al. (2012) designed a programme for teachers to obtain critical appraisal skills and higher academic capacity. Four studies were about developing digital platforms for professional development: Goeze et al. (2014) examined how video case-based learning could promote teachers' analytical competence to become immersed and to adopt multiple perspectives, to apply conceptual knowledge, and to describe pedagogical situations. Similarly, Põldoja et al. (2014) addressed the design challenges of a software solution for self- and peer-assessing teachers' digital competencies. Finally, So et al. (2009) designed an online platform where teachers can share vivid images of their practices with their peers.

Technologies

The studies regarding learning technologies were assigned to the following categories: *Assessment and monitoring tools*, *Educational games*, *Learning and teaching applications*, *safety and security tools*, and *Technology for special needs* (Table 4).

Table 4: Teachers in participatory design of technologies ($n = 28$).

Category	Articles
Assessment and monitoring tools	Gillies et al. (2015), Rodríguez-Triana et al. (2012), Siozos et al. (2009)
Educational games	Hoda et al. (2014), Klonari and Gousiou (2014)
Learning and teaching applications	Carmichael (2015), Cramer and Hayes (2013), Girard and Johnson (2010), Hannon et al. (2012), Kalra et al. (2007), Pedersen et al. (2012), Rahamat et al. (2011), Song and Oh (2016), Su et al. (2010), Triantafyllou and Timcenko (2013)
Safety and security	Ervasti et al. (2016), Jutila et al. (2015), Pantsar-Syväniemi et al. (2015)
Technology for special needs	Abdullah and Brereton (2015), Bossavit and Parsons (2016), Brereton et al. (2015), Medeiros-Braz et al. (2017), Fage et al. (2016), Herstad and Holone (2012), Lingnau and Lenschow (2010), Parsons et al. (2011), Parsons and Cobb (2014), Zainuddin et al. (2010)

In the *Assessment and monitoring tools* category, Gillies et al. (2015) developed an application for giving feedback about students' playing posture in music education. They created a prototype, then asked teachers for feedback before developing next version for evaluation. Rodrigo and Ramírez (2017) developed computer-supported collaborative learning scenarios for monitoring students' interactions. Siozos et al. (2009) reported positive outcomes after involving teachers and students in designing computer-based assessment tools: both teachers and students perceived PD as an opportunity to re-conceptualise existing pedagogies and that PD supported locality, diversity, participation, and attitudes that counter impassivity and homogenisation.

Two of the studies were about *Educational games*. Hoda et al. (2014) involved teachers as part of a multidisciplinary team that designed a game for supporting reciprocal teaching and collaboration with children. They evaluated and refined the game through functional testing, teacher trials, and children–teacher trials. As an outcome, the game was perceived as engaging and easily understood by young children. Klonari and Gousiou (2014) described a game for helping teachers to become aware of their pedagogical choices. The game itself was described in detail, but it remained unclear how the teachers engaged in the design of the game.

The studies in the *Learning and teaching applications* category designed technology for dance and environmental education (Carmichael, 2015), financial education (Cramer and Hayes, 2013), STEM education (Hannon et al., 2012; Su et al., 2010), mathematics (Pedersen et al., 2012; Triantafyllou and Timcenko, 2013), and literature (Rahamat et al., 2011). Three studies examined the development of tutoring systems (Girard and Johnson, 2010; Kalra et al., 2007; Song and Oh, 2016). The studies in this sub-category focused on the technologies themselves. An exception was the study by Carmichael (2015), which criticised the assumptions behind education technology development. That is, it concerned the risks of designing educational technology based on stereotypical views, such as *digital natives*, and losing sight of practice-based knowledge.

All three studies in the *Safety and security* category related to designing a situation-aware safety service. Jutila et al. (2015) examined the technological enablers and requirements for building a safety system, Pantsar-Syväniemi et al. (2015) analysed the design process itself, and Ervasti et al. (2016) analysed the feedback from children, parents, and teachers. Even though the design clearly focused on children, these studies were able to bring together various perspectives from teachers and parents as well.

The largest category was *Technology for special needs*. The studies considered various special needs, such as Autism Disorder, language delays, and cognitive and sensory impairments. Some studies focused on identifying requirements for technology design (Lingnau and Lenschow, 2010; Zainuddin et al., 2010) or describing how technology can support these needs (Abdullah and Brereton, 2015; Fage et al., 2016; Herstad and Holone, 2012; Parsons et al., 2011). Medeiros-Braz et al. (2017) emphasised that teachers have valuable knowledge about students' special needs and can envision technologies to support students' abilities and learning possibilities. In contrast, Brereton et al. (2015) noted that teachers (and other adults) have their own needs, and these can be different than the actual objectives of the students who have special needs.

Finally, two methodological contributions stand out in this category. Bossavit and Parsons (2016) utilised a stakeholder analysis framework to reflect the design process of an educational game. The framework was grounded in PD literature and used to map stakeholder roles, levels of engagement, design tools, and decisions. Parsons and Cobb (2014) addressed the complexity of involving multiple stakeholders: in this case, teachers and children with special needs. They discussed how the key challenge is to prioritise different stakeholders and decisions. They argue that prioritising each stakeholder equally is impossible and question if an outcome-focused agenda, which aims for efficient technology development, is even possible to combine with the empowering approach of PD.

5. Conclusion and discussion

This systematic mapping produced an overview of the current research on PD involving teachers. The mapped studies were assigned into three categories: environments, practices, and technologies. The studies in the environments category involved teachers in designing physical buildings, as well as technologies integrated into the environment. The studies in the practices category considered professional communities, instructional planning, and professional development programmes. The studies in the technologies category designed assessment and monitoring tools, educational games, learning and teaching applications, security and safety technology, and technology for special needs. However, it needs to be noted that producing the categories is not deterministic. Some of the studies could have been assigned to any of the three main categories. For example, So et al. (2009) examined teachers' professional development under the category of practices and could have incorporated the other two categories as well, because it involved online environments and the development of an online video platform.

The mapping revealed valuable assets for conducting PD in educational context: visual tools for triangulating participants' different perspectives (Woolner et al., 2010), stakeholder analysis models (Könings et al., 2017), a tool for mapping and sharing stakeholders' goals (Janssen et al., 2017), and the stakeholder analysis framework (Bossavit and Parsons, 2016). When regarding the involvement of teachers and students, some studies recommended involving them together, while others proposed separating them: Casanova and Mitchell (2017) stated that dividing students and teachers into separate groups offers a more pleasant environment for both, whereas Woolner et al. (2007) warned that the teacher perspective may be pushed to the background if students and teachers are in the same group. This would be an interesting topic to explore further.

Based on the mapping, the advantages of PD for teachers include: possibility to reflect on teaching through PD (Bossen et al., 2010), development of teacher ownership (Kyza and Georgiou, 2014), development of supporting design conditions for teachers (Cober et al., 2015), and teacher's professional development (Kyza and Nicolaidou, 2017). These findings relate to the similar kind of benefits in research about collaborative curriculum design in teacher design teams (Voogt et al., 2011). Another standpoint was how PD was proposed as a way to deal with contradictions between teachers' pedagogical needs and other stakeholders' needs (van Merriënboer et al., 2017; Woolner et al., 2007) and to reduce discrepancies between teachers and students (Könings et al., 2007b, 2010, 2011). However, especially the studies in technology category relied on the assumption that PD would eventually benefit teachers through better learning environments, practices, and technologies, instead of paying specific attention on what are the benefits for teachers.

Literature review and mapping differ in purpose: mapping aims to gather a representative set of studies using inclusion and exclusion criteria and tabulate these studies into specific categories (Kitchenham and Charters, 2007; Kitchenham et al., 2010). The quality of this study can be assessed based on how expansive and rigorous the mapping protocol is. The literature was collected from 14 academic search engines and databases, which is a very wide scope for a single mapping study. The data collection procedure can be repeated, which increases the reliability of the study. If the data were to be collected now (2019), some studies would appear that are not in the original data. This is because new studies have been published since data collection for the present study was concluded in 2018. The exclusion criteria for have been explained in full and the reasons for exclusion recorded for each study, which makes external validation of the mapping possible. This mapping provides a basis for multidisciplinary research about PD in educational context, as been called for by DiSalvo et al. (2017).

References

Abdullah, M.H.L., Brereton, M., 2015. MyCalendar: Fostering Communication for Children with Autism Spectrum Disorder Through Photos and Videos, in: Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI '15, ACM Press, New York, New York, USA. pp. 1–9. doi:10.1145/2838739.2838785.

Al-Eraky, M.M., Donkers, J., Wajid, G., van Merriënboer, J.J., 2015. Faculty development for learning and teaching of medical professionalism. Medical Teacher 37, S40–S46. doi:10.3109/0142159X.2015.1006604.

Anderson, L., Östlund, D., 2017. Assessments for learning in grades 1-9 in a special school for students with intellectual disability in Sweden. Problems of Education in the 21st Century 75, 508–524.

Bang, M., Vossoughi, S., 2016. Participatory Design Research and Educational Justice: Studying Learning and Relations Within Social Change Making. Cognition and Instruction 34, 173–193. doi:10.1080/07370008.2016.1181879.

Barbera, E., Garcia, I., Fuertes-Alpiste, M., 2017. A Co-Design Process Microanalysis: Stages and Facilitators of an Inquiry-Based and Technology-Enhanced Learning Scenario. The International Review of Research in Open and Distributed Learning 18, 104–126. doi:10.19173/irrodl.v18i6.2805.

Beck, E.E., 2002. P for Political: Participation is Not Enough. Scandinavian Journal of Information Systems 14, 77–92. URL: http://folk.uio.no/eevi/research/pub-papers/Beck2002aSJIS.PforPol.ps.

Benton, L., Johnson, H., 2015. Widening participation in technology design: A review of the involvement of children with special educational needs and disabilities. International Journal of Child-Computer Interaction 3-4, 23–40. doi:10.1016/j.ijcci.2015.07.001.

Bjerknes, G., Bratteteig, T., 1995. User participation and democracy: a discussion of Scandinavian research on system development. Scandinavian Journal of Information Systems 7, 73–98.

Bjerknes, G., Ehn, P., Kyng, M., 1987. Computers and Democracy: A Scandinavian Challenge. Gower Press, Brookfield.

Bødker, S., Ehn, P., Sjögren, D., Sundblad, Y., 2000. Co-operative Design — perspectives on 20 years with ' the Scandinavian IT Design Model ', in: NordiCHI 2000, pp. 1–9.

Bødker, S., Kyng, M., 2018. Participatory Design that Matters—Facing the Big Issues. ACM Transactions on Computer-Human Interaction 25, 1–31. doi:10.1145/3152421.

Booker, A., Goldman, S., 2016. Participatory Design Research as a Practice for Systemic Repair: Doing Hand-in-Hand Math Research with Families. Cognition and Instruction 34, 222–235. doi:10.1080/07370008.2016.1179535.

Bossavit, B., Parsons, S., 2016. Designing an Educational Game for and with Teenagers with High Functioning Autism, in: Proceedings of the 14th Participatory Design Conference: Full Papers - Volume 1, ACM, New York, NY, USA. pp. 11–20. doi:10.1145/2940299.2940313.

Bossen, C., Dindler, C., Iversen, O.S., 2010. User gains and PD aims, in: Proceedings of the 11th Biennial Participatory Design Conference on - PDC '10, ACM Press, New York, New York, USA. p. 141. doi:10.1145/1900441.1900461.

Brereton, M., Sitbon, L., Abdullah, M.H.L., Vanderberg, M., Koplick, S., 2015. Design after design to bridge between people living with cognitive or sensory impairments, their friends and proxies. CoDesign 11, 4–20. doi:10.1080/15710882.2015.1009471.

Burke, C., Könings, K.D., 2016. Recovering lost histories of educational design: a case study in contemporary participatory strategies. Oxford Review of Education 42, 721–732. doi:10.1080/03054985.2016.1232244.

Carmichael, P., 2015. Not just about gadgets: Habit, innovation and change in the design of learning technologies. E-Learning and Digital Media 12, 279–294. doi:10.1177/2042753015571052.

Casanova, D., Mitchell, P., 2017. The cube and the poppy: Participatory approaches for designing technology-enhanced learning spaces. Journal of Learning Spaces 6, 1–12.

Cober, R., Tan, E., Slotta, J., So, H.J., Könings, K.D., 2015. Teachers as participatory designers: two case studies with technology-enhanced learning environments. Instructional Science 43, 203–228. doi:10.1007/s11251-014-9339-0.

Cramer, M., Hayes, G.R., 2013. The digital economy, in: Proceedings of the 12th International Conference on Interaction Design and Children - IDC '13, ACM Press, New York, New York, USA. pp. 431–434. doi:10.1145/2485760.2485832.

Cviko, A., McKenney, S., Voogt, J.M., 2014. Teacher roles in designing technology-rich learning activities for early literacy: A cross-case analysis. Computers & Education 72, 68–79. doi:10.1016/j.compedu.2013.10.014.

DiSalvo, B., Yip, J., Bonsignore, E., DiSalvo, C., 2017. Participatory Design for Learning: Perspectives from Practice and Research. First ed., Routledge, New york.

Druin, A., 2002. The role of children in the design of new technology. Behaviour & Information Technology 21, 1–25. doi:10.1080/01449290110108659.

Duell, C., Wright, N., Roxburgh, J., 2014. Developing "Design Minds" for the 21st Century through a Public Sector Initiated Online Design Education Platform. URL: http://ojs.lboro.ac.uk/ojs/index.php/DATE/article/view/1926/1968.

Ehn, P., 1988. Work-Oriented Design of Computer Artifacts. Ph.D. thesis. Umeå Universitat. URL: http://www.diva-portal.org/smash/record.jsf?pid=diva2:580037&dswid=-8358.

Ervasti, M., Laitakari, J., Hillukkala, M., 2016. 'I want to know where my child is at all times' – field study of a location-aware safety service for schoolchildren. Behaviour & Information Technology 35, 833–852. doi:10.1080/0144929X.2016.1201144.

European Commission, 2018. Communication on the Digital Education Action Plan. Technical Report. European Comission. Brussels. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:22:FIN.

Fage, C., Pommereau, L., Consel, C., Balland, E., Sauzéon, H., 2016. Tablet-Based Activity Schedule in Mainstream Environment for Children with Autism and Children with ID. ACM Transactions on Accessible Computing 8, 1–26. doi:10.1145/2854156.

Farooq, U., Schank, P., Harris, A., Fusco, J., Schlager, M., 2007. Sustaining a Community Computing Infrastructure for Online Teacher Professional Development: A Case Study of Designing Tapped In. Computer Supported Cooperative Work (CSCW) 16, 397–429. doi:10.1007/s10606-007-9049-0.

Frauenberger, C., Good, J., Fitzpatrick, G., Iversen, O.S., 2015. In pursuit of rigour and accountability in participatory design. International Journal of Human-Computer Studies 74, 93–106. doi:10.1016/j.ijhcs.2014.09.004.

Gillies, M., Brenton, H., Yee-King, M., Grimalt-Reynes, A., D'Inverno, M., 2015. Sketches vs skeletons, in: Proceedings of the 2nd International Workshop on Movement and Computing - MOCO '15, ACM Press, New York, New York, USA. pp. 104–111. doi:10.1145/2790994.2790995.

Girard, S., Johnson, H., 2010. Designing affective computing learning companions with teachers as design partners., in: Proceedings of the 3rd international workshop on Affective interaction in natural environments - AFFINE '10, ACM Press, New York, New York, USA. p. 49. doi:10.1145/1877826.1877840.

Goeze, A., Zottmann, J.M., Vogel, F., Fischer, F., Schrader, J., 2014. Getting immersed in teacher and student perspectives? Facilitating analytical competence using video cases in teacher education. Instructional Science 42, 91–114. doi:10.1007/s11251-013-9304-3.

Greenbaum, J., 1993. PD a personal statement. Communications of the ACM 36, 47. doi:10.1145/153571.214816.

Gregory, J., 2003. Scandinavian Approaches to Participatory Design. International Journal of Engaging Education 19, 62–74.

Gros, B., López, M., 2016. Students as co-creators of technology-rich learning activities in higher education. International Journal of Educational Technology in Higher Education 13, 28. doi:10.1186/s41239-016-0026-x.

Halskov, K., Hansen, N.B., 2015. The diversity of participatory design research practice at PDC 2002–2012. International Journal of Human-Computer Studies 74, 81–92. doi:10.1016/j.ijhcs.2014.09.003.

Hannon, D., Danahy, E., Schneider, L., Coopey, E., Garber, G., 2012. Encouraging teachers to adopt inquiry-based learning by engaging in participatory design, in: IEEE 2nd Integrated STEM Education Conference, IEEE, Department of Mechanical Engineering/Human Factors, Tufts University, United States. pp. 1–4. doi:10.1109/ISECon.2012.6204169.

Harrison, C.J., Könings, K.D., Schuwirth, L.W.T., Wass, V., van der Vleuten, C.P.M., 2017. Changing the culture of assessment: the dominance of the summative assessment paradigm. BMC Medical Education 17, 73. doi:10.1186/s12909-017-0912-5.

Herstad, J., Holone, H., 2012. What we talk about when we talk about co-creative tangibles, in: Proceedings of the 12th Participatory Design Conference on Exploratory Papers Workshop Descriptions Industry Cases - Volume 2 - PDC '12, ACM Press, New York, New York, USA. p. 109. doi:10.1145/2348144.2348179.

Hoda, R., Henderson, A., Lee, S., Beh, B., Greenwood, J., 2014. Aligning technological and pedagogical considerations: Harnessing touch-technology to enhance opportunities for collaborative gameplay and reciprocal teaching in NZ early education. International Journal of Child-Computer Interaction 2, 48–59. doi:10.1016/j.ijcci.2014.06.001.

Hussain, S., 2010. Empowering marginalised children in developing countries through participatory design processes. CoDesign 6, 99–117. doi:10.1080/15710882.2010.499467.

Iivari, J., Iivari, N., 2006. Varieties of User-Centeredness, in: Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06), IEEE. pp. 176a–176a. doi:10.1109/HICSS.2006.530.

Ishimaru, A.M., Takahashi, S., 2017. Disrupting Racialized Institutional Scripts Toward Parent-Teacher Transformative Agency for Educational Justice. Peabody Journal of Education 92, 343–362. doi:10.1080/0161956X.2017.1324660.

Iversen, O.S., Dindler, C., 2013. A Utopian agenda in child-computer interaction. International Journal of Child-Computer Interaction 1, 24–29. doi:10.1016/j.ijcci.2012.08.002.

Iversen, O.S., Halskov, K., Leong, T.W., 2012. Values-led participatory design. CoDesign 8, 87–103. doi:10.1080/15710882.2012.672575.

Janssen, F., Könings, K.D., van Merriënboer, J.J., 2017. Participatory educational design: How to improve mutual learning and the quality and usability of the design? European Journal of Education 52, 268–279. doi:10.1111/ejed.12229.

Janssen, F.J.J.M., Westbroek, H.B., van Driel, J.H., 2014. How to make guided discovery learning practical for student teachers. Instructional Science 42, 67–90. doi:10.1007/s11251-013-9296-z.

Joyce, C., Pham, H., Stanton Fraser, D., Payne, S., Crellin, D., McDougall, S., 2014. Building an internet of school things ecosystem, in: Proceedings of the 2014 conference on Interaction design and children - IDC '14, ACM Press, New York, New York, USA. pp. 289–292. doi:10.1145/2593968.2610474.

Jutila, M., Strömmer, E., Ervasti, M., Hillukkala, M., Karhula, P., Laitakari, J., 2015. Safety services for children: a wearable sensor vest with wireless charging. Personal and Ubiquitous Computing 19, 915–927. doi:10.1007/s00779-015-0838-z.

Kalra, N., Lauwers, T., Dewey, D., Stepleton, T., Dias, M.B., 2007. Iterative design of a Braille writing tutor to combat illiteracy, in: 2007 International Conference on Information and Communication Technologies and Development, IEEE, RAND corporation, United States. pp. 1–9. doi:10.1109/ICTD.2007.4937386.

Karimi, A., Worthy, P., McInnes, P., Bodén, M., Matthews, B., Viller, S., 2017. The Community Garden Hack: Participatory Experiments in Facilitating Primary School Teacher's Appropriation of Technology, in: Proceedings of the 29th Australian Conference on Computer-Human Interaction, ACM, New York, NY, USA. pp. 143–151. doi:10.1145/3152771.3152787.

Kensing, F., Blomberg, J., 1998. Participatory Design: Issues and Concerns. Computer Supported Cooperative Work (CSCW) 7, 167–185. doi:10.1023/A:1008689307411.

Kitchenham, B., Charters, S., 2007. Guidelines for performing Systematic Literature reviews in Software Engineering. Technical Report. doi:10.1145/1134285.1134500, arXiv:1304.1186.

Kitchenham, B., Pretorius, R., Budgen, D., Brereton, O.P., Turner, M., Niazi, M., Linkman, S., 2010. Systematic literature reviews in software engineering-A tertiary study. Information and Software Technology 52, 792–805. doi:10.1016/j.infsof.2010.03.006.

Klonari, A., Gousiou, A., 2014. Encouraging teachers' reflection using a card game: The game of consequences, in: Proceedings of the European Conference on Games-based Learning, Dept of Geography, University of the Aegean, Mytilene, Greece. pp. 279–285.

Könings, K.D., Bovill, C., Woolner, P., 2017. Towards an interdisciplinary model of practice for participatory building design in education. European Journal of Education 52, 306–317. doi:10.1111/ejed.12230.

Könings, K.D., Brand-Gruwel, S., van Merriënboer, J.J., 2007a. Teachers' perspectives on innovations: Implications for educational design. Teaching and Teacher Education 23, 985–997. doi:10.1016/j.tate.2006.06.004.

Könings, K.D., Brand-Gruwel, S., van Merriënboer, J.J., 2010. An approach to participatory instructional design in secondary education: an exploratory study. Educational Research 52, 45–59. doi:10.1080/00131881003588204.

Könings, K.D., Brand-Gruwel, S., van Merriënboer, J.J., 2011. Participatory instructional redesign by students and teachers in secondary education: effects on perceptions of instruction. Instructional Science 39, 737–762. doi:10.1007/s11251-010-9152-3.

Könings, K.D., McKenney, S., 2017. Participatory design of (built) learning environments. European Journal of Education 52, 247–252. doi:10.1111/ejed.12232.

Könings, K.D., Seidel, T., van Merriënboer, J.J., 2014. Participatory design of learning environments: integrating perspectives of students, teachers, and designers. Instructional Science 42, 1–9. doi:10.1007/s11251-013-9305-2.

Könings, K.D., van Zundert, M.J., Brand-Gruwel, S., van Merriënboer, J.J., 2007b. Participatory design in secondary education: is it a good idea? Students' and teachers' opinions on its desirability and feasibility. Educational Studies 33, 445–465. doi:10.1080/03055690701423648.

Koutamanis, A., Heuer, J., Könings, K.D., 2017. A visual information tool for user participation during the lifecycle of school building design: BIM. European Journal of Education 52, 295–305. doi:10.1111/ejed.12226.

Kreitmayer, S., Rogers, Y., Laney, R., Peake, S., 2013. UniPad: Orchestrating Collaborative Activities Through Shared Tablets and An Integrated Wall Display, in: Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing - UbiComp '13, ACM Press, New York, New York, USA. p. 801. doi:10.1145/2493432.2493506.

Kuure, L., Molin-Juustila, T., Keisanen, T., Riekki, M., Iivari, N., Kinnula, M., 2016. Switching perspectives: from a language teacher to a designer of language learning with new technologies. Computer Assisted Language Learning 29, 925–941. doi:10.1080/09588221.2015.1068815.

Kyza, A.E., Georgiou, Y., 2014. Developing In-Service Science Teachers' Ownership of the Profiles Pedagogical Framework through a Technology-Supported Participatory Design Approach to Professional Development. Science Education International 25, 21.

Kyza, E.A., Nicolaidou, I., 2017. Co-designing reform-based online inquiry learning environments as a situated approach to teachers' professional development. CoDesign 13, 261–286. doi:10.1080/15710882.2016.1209528.

Leong, T.W., Iversen, O.S., 2015. Values-led Participatory Design as a Pursuit of Meaningful Alternatives, in: Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI '15, ACM Press, New York, New York, USA. pp. 314–323. doi:10.1145/2838739.2838784.

Lingnau, A., Lenschow, H., 2010. Scenarios for computersupported learning in a special needs classroom. Journal of Assistive Technologies 4, 26–35. doi:10.5042/jat.2010.0279.

Lundström, A., Savolainen, J., Kostiainen, E., 2016. Case study: developing campus spaces through co-creation. Architectural Engineering and Design Management 12, 409–426. doi:10.1080/17452007.2016.1208077.

Medeiros-Braz, L., Souza Ramos, E., Benedetti, M.L.P., Hornung, H., 2017. Participatory Design of Technology for Inclusive Education: A Case Study, in: Lecture Notes in Computer Science, Springer Verlag, Campinas. pp. 168–187. doi:10.1007/978-3-319-58700-4.

van Merriënboer, J.J., McKenney, S., Cullinan, D., Heuer, J., 2017. Aligning pedagogy with physical learning spaces. European Journal of Education 52, 253–267. doi:10.1111/ejed.12225.

OECD, 2015. Education Policy Outlook 2015: Making Reforms Happen. Technical Report. Paris. URL: `http://www.oecd-ilibrary.org/education/education-policy-outlook-2015_9789264225442-en`, doi:10.1787/9789264225442-en.

Otero, N., Alissandrakis, A., Müller, M., Milrad, M., Lencastre, J.A., Casal, J., José, R., 2013. Promoting secondary school learners' curiosity towards science through digital public displays, in: Proceedings of International Conference on Making Sense of Converging Media - AcademicMindTrek '13, ACM Press, New York, New York, USA. pp. 204–210. doi:10.1145/2523429.2523475.

Pantsar-Syväniemi, S., Ervasti, M., Karppinen, K., Väätänen, A., Oksman, V., Kuure, E., 2015. A situation-aware safety service for children via participatory design. Journal of Ambient Intelligence and Humanized Computing 6, 279–293. doi:10.1007/s12652-014-0225-z.

Parsons, S., Cobb, S., 2014. Reflections on the role of the 'users': challenges in a multi-disciplinary context of learner-centred design for children on the autism spectrum. International Journal of Research & Method in Education 37, 421–441. doi:10.1080/1743727X.2014.890584.

Parsons, S., Millen, L., Garib-Penna, S., Cobb, S., 2011. Participatory design in the development of innovative technologies for children and young people on the autism spectrum: the COSPATIAL project. Journal of Assistive Technologies 5, 29–34. doi:10.5042/jat.2011.0099.

Pedersen, J.B., Andersen, A.S.Ö., Majgaard, G., 2012. Design of trigonometry apps for vocational education, in: Proceedings of the IASTED International Conference on Human-Computer Interaction, HCI 2012, Itai a/s, Ndr. Landevej 2a, DK-6270 T{ø}nder, Denmark. pp. 226–232. doi:10.2316/P.2012.772-020.

Pérez-Sanagustín, M., Nussbaum, M., Hilliger, I., Alario-Hoyos, C., Heller, R.S., Twining, P., Tsai, C.C., 2017. Research on ICT in K-12 schools – A review of experimental and survey-based studies in computers and education 2011 to 2015. Computers & Education 104, A1–A15. doi:10.1016/j.compedu.2016.09.006.

Pilemalm, S., 2018. Participatory Design in Emerging Civic Engagement Initiatives in the New Public Sector. ACM Transactions on Computer-Human Interaction 25, 1–26. doi:10.1145/3152420.

Põldoja, H., Väljataga, T., Laanpere, M., Tammets, K., 2014. Web-based self- and peer-assessment of teachers' digital competencies. World Wide Web 17, 255–269. doi:10.1007/s11280-012-0176-2.

Pollock, M., Amaechi, U., 2013. Texting as a channel for personalized youth support: participatory design research by city

youth and teachers. Learning, Media and Technology 38, 128–144. doi:10.1080/17439884.2013.756516.
Prins, G., Bulte, A., Pilot, A., 2016. An Activity-Based Instructional Framework for Transforming Authentic Modeling Practices into Meaningful Contexts for Learning in Science Education. Science Education 100, 1092–1123. doi:10.1002/sce.21247.
Rahamat, R., Shah, P.M., Nor Puteh, S., Din, R., Karim, A.A., 2011. End-users' involvement in the development of web-based learning resources for English literature. 3L: The Southeast Asian Journal of English Language Studies 17, 5–18.
Reeves, T.C., 2015. Educational design research: Signs of progress. Australasian Journal of Educational Technology 31, 613–620.
Rodrigo, R., Ramírez, C.D., 2017. Balancing Institutional Demands with Effective Practice: A Lesson in Curricular and Professional Development. Technical Communication Quarterly 26, 314–328. doi:10.1080/10572252.2017.1339529.
Rodríguez-Triana, M.J., Martínez-Monés, A., Asensio-Pérez, J.I., Dimitriadis, Y., 2012. Towards a Monitoring-Aware Design Process for CSCL Scripts. doi:10.1007/978-3-642-33284-5.
Sanders, E.B.N., Stappers, P.J., 2008. Co-creation and the new landscapes of design. CoDesign 4, 5–18. doi:10.1080/15710880701875068.
Santally, M.I., Cooshna-Naik, D., Conruyt, N., Wing, C.K., 2015. A Social Partnership Model to Promote Educators' Development in Mauritius through Formal and Informal Capacity-Building Initiatives. Journal of Learning for Development 2, 9.
Selwyn, N., Henderson, M., Chao, S.H., 2017. The possibilities and limitations of applying 'open data' principles in schools. Cambridge Journal of Education 47, 167–187. doi:10.1080/0305764X.2016.1143449.
Simonsen, J., Robertson, T., 2013. Routledge International Handbook of Participatory Design. Routledge, New York.
Siozos, P., Palaigeorgiou, G., Triantafyllakos, G., Despotakis, T., 2009. Computer based testing using "digital ink": Participatory design of a Tablet PC based assessment application for secondary education. Computers & Education 52, 811–819. doi:10.1016/j.compedu.2008.12.006.
Smith, R.C., Bossen, C., Kanstrup, A.M., 2017. Participatory design in an era of participation. CoDesign 13, 65–69. doi:10.1080/15710882.2017.1310466.
So, H.J., Lossman, H., Lim, W.Y., Jacobson, M.J., 2009. Designing an online video based platform for teacher learning in Singapore. Australasian Journal of Educational Technology 25, 440–457.
Somerville, M.M., Collins, L., 2008. Collaborative design: a learner-centered library planning approach. The Electronic Library 26, 803–820. doi:10.1108/02640470810921592.
Song, D., Oh, E.Y., 2016. A Participatory Design Approach for a Mobile App-Based Personal Response System. Journal of Educational Technology Systems 44, 346–361. doi:10.1177/0047239515618465.
Spinuzzi, C., 2002. A Scandinavian challenge, a US response, in: Proceedings of the 20th annual international conference on Computer documentation - SIGDOC '02, ACM Press, New York, New York, USA. pp. 208–215. doi:10.1145/584955.584986.
Steen, M., 2011. Tensions in human-centred design. CoDesign 7, 45–60. doi:10.1080/15710882.2011.563314.
Stephen, M.L., Locke, S.M., Bracey, G.L., 2014. Using a Participatory Design Approach to Create and Sustain an Innovative Technology-rich STEM Classroom - One School's Story, in: Proceedings of the 6th International Conference on Computer Supported Education, SCITEPRESS - Science and and Technology Publications, Center for Science, Technology, Engineering and Mathematics Research, Education, and Outreach, Southern Illinois University, Edwardsville, IL, United States. pp. 30–38. doi:10.5220/0004849900300038.
Su, C., Chiu, C., Wang, T., 2010. The development of SCORM-conformant learning content based on the learning cycle using participatory design. Journal of Computer Assisted Learning 26, 392–406. doi:10.1111/j.1365-2729.2010.00355.x.
Suchman, L., 1988. Designing with the user: book review of Computers and democracy: a Scandinavian challenge, G. Bjerknes, P. Ehn, and M. Kyng, Eds. Gower Press, Brookfield, VT, 1987. ACM Transactions on Information Systems 6, 173–183. doi:10.1145/45941.383895.
Tammets, K., Pata, K., Laanpere, M., Tomberg, V., Gašević, D., Siadaty, M., 2011. Designing the competence-driven teacher accreditation. doi:10.1007/978-3-642-25813-8.
Triantafyllou, E., Timcenko, O., 2013. Developing digital technologies for university mathematics by applying participatory design methods, in: 2013 24th EAEEIE Annual Conference (EAEEIE 2013), IEEE, Dept. of Media Technology, Aalborg University Copenhagen, A.C. Meyers Vaenge 15, DK-2450 Copenhagen SV, Denmark. pp. 82–85. doi:10.1109/EAEEIE.2013.6576507.
Tulinius, C., Brit, A., Nielsen, S., Hansen, L.J., Hermann, C., Vlasova, L., Dalsted, R., 2012. Increasing the general level of academic capacity in general practice: Introducing mandatory research training for general practitioner trainees through a participatory research process. Quality in Primary Care 20, 57–67.
Vakil, S., McKinney de Royston, M., Suad Nasir, N., Kirshner, B., 2016. Rethinking Race and Power in Design-Based Research: Reflections from the Field. Cognition and Instruction 34, 194–209. doi:10.1080/07370008.2016.1169817.
Vines, J., Clarke, R., Light, A., Wright, P., 2015. The beginnings, middles and endings of participatory research in HCI: An introduction to the special issue on 'perspectives on participation'. International Journal of Human-Computer Studies 74, 77–80. doi:10.1016/j.ijhcs.2014.11.002.
Voogt, J.M., Westbroek, H., Handelzalts, A., Walraven, A., McKenney, S., Pieters, J., de Vries, B., 2011. Teacher learning in collaborative curriculum design. Teaching and Teacher Education 27, 1235–1244. doi:10.1016/j.tate.2011.07.003.
Wang, F., Hannafin, M.J., 2005. Design-based research and technology-enhanced learning environments. Educational Technology Research and Development 53, 5–23. doi:10.1007/BF02504682, arXiv:arXiv:1011.1669v3.
Woolner, P., Clark, J., Hall, E., Tiplady, L., Thomas, U., Wall, K., 2010. Pictures are necessary but not sufficient: Using a range of visual methods to engage users about school design. Learning Environments Research 13, 1–22. doi:10.1007/s10984-009-9067-6.
Woolner, P., Hall, E., Wall, K., Dennison, D., 2007. Getting together to improve the school environment: user consultation,

participatory design and student voice. Improving Schools 10, 233–248. doi:10.1177/1365480207077846.
Zainuddin, N.M.M., Zaman, H.B., Ahmad, A., 2010. A Participatory Design in Developing Prototype an Augmented Reality Book for Deaf Students, in: 2010 Second International Conference on Computer Research and Development, IEEE, Department of Information Science, Universiti Kebangsaan Malaysia, Bangi Selangor, Malaysia. pp. 400–404. doi:10.1109/ICCRD.2010.55.

Appendix

Reference	Research purpose	Analysis / validation method	Main findings
Abdullah and Brereton (2015)	Support children with Autism Disorder and language delays.	Thematical analysis (Boyatzis, 1998; Braun and Clarke, 2006) of video clips and observational notes on interactions between teachers and children.	Teachers could model positive behaviours and to scaffold more relevant and meaningful learning opportunities by relating them to the children's lives.
Al-Eraky et al. (2015)	Design a faculty development programme on professionalism.	Kirkpatrick's (1994) model for programme outcomes evaluation 1) reaction, 2) learning, 3) behaviour, and 4) results.	1) developing vignettes on professionalism is difficult 2) some vignettes help learners prioritise their lives, 3) different versions from a vignette. Teachers became more knowledgeable on professionalism and how it can be taught.
Anderson and Östlund (2017)	Analyze teachers and paraprofessionals' work and reflections in AfL during a professional development project in a special school.	Research is based on the four teams' documentation (written texts) of their work and analyzed using a qualitative content analysis (Graneheim and Lundman, 2004).	Contributes to the assessment of learners attending special schools, an assessment practice that is still in its infancy and needs to be further developed through extensive studies.
Barbera et al. (2017)	Identify the moments of change that occur during the co-design process and secondly, to describe the causes and agents that motivate them.	Descriptions of agents' main roles and changes between three different co-designed versions of learning scenarios.	Developing contextualised theory on the domain of IBL and TEL pedagogical models as well as on the co-design process itself. A qualitative approach was used for data collection, analysis, and interpretation.
Booker and Goldman (2016)	Tackle math fears by restoring families' epistemic authority.	Four years of design, facilitation, and dissemination of workshops, take-home materials, and family case studies.	1) open dialogue about what counts as the phenomenon of interest, 2) simultaneous positioning to learners and authors in ways of knowing, 3) collaborative data analysis, 4) removal of individual and cultural deficit.
Bossavit and Parsons (2016)	Design an educational game to learn about Geography via the use of Natural User Interfaces.	Stakeholders contribute their own spheres of expertise and equity in design partnership is not about all partners sharing all decisions, but about respectfully managing the different expertise that each partner brings.	Mapping of design sessions: 1) stakeholder role, 2) level of engagement, 3) design tools, 4) made decisions, 5) power-sharing.
Bossen et al. (2010)	What participants gain from PD projects?	Single-person, semi-structured interviews (Kvale, 1996) with a focus on exploring the participants' experiences and gains from the project, 1) influence on project, 2) satisfying and frustrating experiences, 3) personal gain, 4) new possibilities and areas of competence.	1) opportunity to reflect on teaching and to communicate across professional borders, 2) skilled in understanding technology, 3) higher influence on related to technology.
Brereton et al. (2015)	Finding possibilites for teachers to facilitate communication with persons with intellectual disability or form of cognitive or sensory impairment.	Elaborating the design after design process when the prototypes were utilised.	Utilising prototypes fostered new forms of social interaction and expression between teachers and persons with impairments.
Burke and Könings (2016)	Describe how designing in education context is informed, inspired, and influenced by the past practices, experiences, and mythologies.	Reflecting the history of De Werkplaats and how it was present in designing the new school.	The power of past experience and the vision of its founder can be recognised as a powerful force in the participatory design process of the new building, which revitalises the educational principles that the school strives for.

Reference	Research purpose	Analysis / validation method	Main findings
Carmichael (2015)	Reflecting technology design in terms of Deleuze's dimensions of time.	Reflecting observations from PD workshops in two case studies.	Syntheses of time involves conversations not just about creating a technology-rich educational utopia or constantly specifying new gadgets, but the troubling of existing pedagogical practices and the multiplication of perspectives and subjectivities.
Casanova and Mitchell (2017)	Investigates new ways of designing learning spaces that are future-proof and relevant for users and discusses the purpose and value of technologies in such learning spaces.	Establishing a creative space (sandpit) wherein students and teachers critically reflect on the purpose and value of technologies and co-create new proposals for technology-enhanced learning spaces. Qualitative analysis of recordings.	Found participatory design as an effective method to anticipate the learning and teaching spaces of the next decade.
Cober et al. (2015)	In what ways teachers participated in the design process and what conditions supported them in their design work?	Ppen coding of design documentation and teacher interviews and utilising discourse analysis using the codes from Muller and Kuhn (1993).	Participation: engaging in theoretical discussions, active participation in a design partnership, reflection about pedagogy and practice, and experimenting with enactment. Support: supporting emergent processes, cultivating an atmosphere of trust and partnership, and designing with contextual knowledge.
Cramer and Hayes (2013)	How empirical work at elementary school informs the design of mobile applications for teachers to manage financial education?	Analysing and coding classroom observations, semi-structured interviews, and field notes.	Three guidelines for designing for classrooms: classroom flow, individual assesment, and peer groups.
Medeiros-Braz et al. (2017)	Investigates the hypothesis that Participatory Design with inclusive education teachers facilitates the creation of technology for inclusion in the classroom (Tangible User Interfaces).	The interpretation of video transcriptions and material created during the workshops was done by the HCI researcher.	Participation benefits the process of inclusion in the classroom of the regular school, since it enables thinking about how to eliminate barriers that prevent students from access to knowledge, the school environment, and the people there.
Duell et al. (2014)	A framework for incorporating design thinking as a generic capability in K-12 education in regional areas of Australia	Validation is discussed in future research, but not done in the study	Establishment of Design Minds community and yearly ambassador program.
Ervasti et al. (2016)	1) learn about needs and perspectives to provide a location-aware safety service that is perceived positive and enabling, 2) test the service, and 3) analyse service experience and value for end-users.	User experience testing, interviews, feedback questionnaires, log data from the safety service system.	Teachers experienced that the safety service did not bring real added value and use to their practical work, mostly due to the fact that there had been only minor exceptions (absences and late arrivals) on normal schooldays during the trial period.
Fage et al. (2016)	Design of a tablet-based application to support activity schedules for both classroom and verbal communication routines	Data from application, questionnaires, comparison between two children groups.	1) children with ID are not autonomous in the use of the application at the end of the intervention. 2) both groups exhibited the same benefits on classroom routines. 3) children with ID improve significantly less their performance on verbal communication routines.
Farooq et al. (2007)	How to design and develop sustainable community computing infrastructures: nine years of design experience with Tapped In – an online community of practice for education professionals	Case descriptions (Yin 2013), discourse analysis (Schlager et al., 2002), collective reflecting of data interpretations	Presenting the design interventions as a measure of success in iteratively designing the artefact and keeping the community members interested in using the infrastructure for online teacher professional development and social networking.

Reference	Research purpose	Analysis / validation method	Main findings
Gillies et al. (2015)	Technology to support music teachers in giving feedback on students' posture and the effectiveness of motion capture in music teaching.	Piloting the developed system with teachers and having a group-feedback session.	The problem of skeletal motion capture for feedback was that it leaved out cues that are required to detect posture problems.
Girard and Johnson (2010)	Design computational models of emotions for use in computational agents embodied in intelligent tutoring systems.	Teachers were asked to rate the usefulness of this emotional response for the pedagogical role within the software and provide with a description of how such responses could be better associated with the pedagogical goal.	Not enough data was collected to present viable results.
Goeze et al. (2014)	How video case-based learning could promote the analytical competence of teachers 1) to become immersed and to adopt multiple perspectives, 2) to apply conceptual knowledge, and 3) to describe pedagogical situations	A coding scheme for measuring the analytical competence of the participants and statistical comparison of experimental groups.	Training teachers to become immersed in the student perspective can be considered as an alternative for direct involvement of students in the design process. Usage of cases plays a role in facilitating analytical skills, and that instructional support is crucial, but only if hyperlinks to multiple perspectives or conceptual knowledge were provided.
Gros and López (2016)	Is the Learner Centric Ecology of Resources model useful to support the selection of the resources using a co-design methodology and how are students influenced by participating in a co-design process to build a learning environment supported by technology.	Interviews with teachers and students in order to identify the main characteristics of the participants, participant observation and audio recordings of joint work sessions, and questionnaires addressed to both teachers and students after each work session.	Framework was identified by the participants as a good facilitator of the co-design process as it helped to identify the main resources for the different scenarios and encouraged dialogue and cooperation among the participants.
Hannon et al. (2012)	Develop classroom educational technology tools for promoting collaborative inquiry-based learning.	Classroom observations, task analysis, PD workshops, but the results are not validated.	By participating in a technology-design project, teachers are experiencing the inquiry process as well as developing tools that will facilitate using inquiry-based methods in their classrooms.
Harrison et al. (2017)	Explore an institution's readiness to adopt initial changes which would help an organisation move towards an assessment for learning culture: 1) opportunities and challenges, 2) individual beliefs.	Participatory redesing meetings and follow-up interviews. Data were analysed from a sociocultural perspective, using Johnson's cultural web as a lens , in order to understand aspects of the organisational culture as well as individual beliefs.	1) the need for more authentic assessment, 2) the potential to give feedback without (or before) the issuing of grades, and 3) the role of one-to-one mentoring to support the interpretation of the feedback.
Herstad and Holone (2012)	Use co-creative tangibles to improve health for persons with severe disabilities.	Prototyping.	The co-creative tangibles in the RHYME project opens up new ways of participation within the fields of Universal Design and tangible interaction.
Hoda et al. (2014)	Design and develop an engaging software solution that would preserve the principles of reciprocal teaching and support collaborative gameplay among teachers and children.	1) functional testing and informal feedback, 2) teacher trials and refinements, and 3) children-teacher trials. Analysis: thematic analysis and open coding sought evidence of reciprocal teaching and collaboration, while remaining open to other emerging patterns.	Interaction with the game was engaging and easily understood by young children, provides evidence that the design features of themed content and mutual awareness, availability of information, and control support reciprocal teaching, collaboration, and collaborative gameplay.

Reference	Research purpose	Analysis / validation method	Main findings
Ishimaru and Takahashi (2017)	Illustrate how codesign concepts and practices that draw from participatory design research methodologies (Bang and Vossoughi, 2016) might disrupt and shift the racialized institutional scripts about nondominant parents to build transformative agency between them and teachers.	Methodological approach is situated within an emerging set of approaches referred to as participatory design-based research study.	Authors suggest that bringing together concepts from organizational theory and sociocultural learning theory can deepen our understandings and strengthen social change interventions. These concepts address the moment-to-moment interactions that are shaped by – and also have untapped ability to transform – the broader institutional structures that reinforce oppression in schools and school systems.
Janssen et al. (2017)	1) view classroom teaching as bounded rational design, 2) develop a laddering tool that supports participants to map and share their multiple goals related to the design of learning environments, and 3) develop a building block tool that helps participants to explore practical and effective possibilities for the design of the learning environment.	Demonstrate how these tools can be used in a design process to improve the quality and usability of learning environments, including physical learning spaces that better support learning.	Even participants with a similar background need tools to learn more about each other's practice and goals, as well as to co-design possible ways of teaching that suit their needs. Participatory design of the learning environment is an important prerequisite for a productive (re-)design of a shared classroom.
Janssen et al. (2014)	Develop a teacher training trajectory for developing guided discovery learning lessons in biology.	Identified the lesson segments and heuristics, and estimated the expected values and underlying motivational beliefs.	Biology student teachers 1) proved to be willing and capable to implement GDL aspects in their lessons, 2) increasingly used the heuristics developed by experienced teachers for designing GDL lessons, 3) willingness to use the heuristics for designing GDL lessons increased after the intervention, 4) both the estimated desirability and probability of GDL lessons increased, and 5) most student teachers the expected value of GDL after the trajectory was higher than the expected value of their regular lessons.
Joyce et al. (2014)	Design an Internet of Things based ecosystem for schools.	Eight-month design and pilot phase, including open-ended interviews, focus groups, training sessions, classroom observation, and shadowing.	Schools were willing to adopt the IoT technology within certain bounds. Outline best practices uncovered when introducing IoT technologies to schools.
Jutila et al. (2015)	Technological enablers and requirements for building a complete end-to-end energy-efficient safety system.	PD workshops, piloting, and evaluation. User questionnaire, technical evaluation.	Insights regarding the monitoring of the child on a situation basis. A novel energy-efficient solution through the designed sensor vest with wireless integrated charging and related end-to-end service applications.
Kalra et al. (2007)	Develop Braille, a prototype writing tutor system to tackle illiteracy	Six week pilot study, learning measurements, acceptance questionnaire, and usability observations	The Braille Writing Tutor has great potential to inexpensively and effectively aid the education of a large number of blind students in the developing world.
Karimi et al. (2017)	Involving teachers in the design process as agile appropriators who outlook technologies as working material and examine how designers can enable a space for this involvement and engagement to co-create and co-explore technology possibilities with and for teachers.	A theme identification based on analysing data from the transcribed workshop feedback.	The teachers' primary takeaway was the pedagogical concept of collaborative problem solving with technology and they found ways to appropriate the process to provide similar experiences for their students.

Reference	Research purpose	Analysis / validation method	Main findings
Klonari and Gousiou (2014)	Develop a Game of Consequences to increase of teachers' awareness on the consequences of their choices for different stakeholders/aspects by reflecting on several dilemmas related to school reality	Game description, but no analysis/validation.	Game 1) outlines a social script for participants to come together and process materials about challenging situations and dilemmas that could encountered at their working spaces/schools, 2) encourages and facilitates reflection in a meaningful way, and 3) encourages critical thinking.
Koutamanis et al. (2017)	Elaborate on an example of a visual information technology tool - Building Information Modelling (BIM) – in the new context of participatory design of the built learning environment.	Elaborating how BIM was used in four stages of building design: 1) initiative, 2) development, 3) realization, and 4) operation.	A comparison of the potential of digital, integrated information tools, such as in BIM, and a successful conventional participatory design project shows that appropriate information technologies can empower users such as school management, teachers and students to become full participants in the entire life cycle of a school building.
Kreitmayer et al. (2013)	Encourage students to talk, collaborate, and make decisions together in real time by switching between working on shared small group devices and a whole classroom public display (UniPad).	Participatory design with expert finance educators and then evaluating the UniPad application at a school.	The UniPad set-up was able to encourage much switching between small and large group discussions. In particular, the students were highly engaged with each other when taking part in the financial decision-making activity.
Kuure et al. (2016)	Support students of English in a Finnish university in switching their career perspective: they were to become not only language teachers but also designers of language learning with new technologies.	Two qualitative approaches: 1) the research strategy of nexus analysis (Scollon and Scollon, 2004) and, 2) design-oriented cultural–historical activity theory (Kuutti, 1994, 2005; Molin-Juustila, 2006).	The PD approach applied in the project was obviously not enough in helping the language students see themselves as designers for the future. Therefore, the students largely failed to engage their pupils as crucial participants in the design process.
Kyza and Georgiou (2014)	PD as a bottom-up approach for promoting teachers' sense of ownership of inquiry-based learning and teaching approach.	1) open ended questionnaire analysed by employing the Attride-Stirling's (2001) thematic network analysis, 2) data corpus was analyzed in a two phase analysis (Patton, 2000), focused on teachers' utterances and used an open coding approach without any predetermined categories, and 3) quantitative data with the MoLE motivation instrument (Bolte, 2012).	The use of technological mediation and the combination of tools that can support teachers' asynchronous and synchronous communication, authoring tools to support the design process, and human scaffolding of teachers' discussions and enactment processes could contribute to the development of a better understanding of the inquiry process and could lead to motivating learning environments for students.
Kyza and Nicolaidou (2017)	Examine co-design as an informal context for teachers' professional development on reform initiatives such as inquiry-based learning	Thematic analysis, open coding, nonparametric and parametric tests of students' pre- and post-tests.	Co-design is a viable approach for transformative teacher professional development, which can support teachers in developing knowledge and skills to address their just-in-time needs.
Könings et al. (2017)	Explore how architects, educational designers, teachers, and students can collaborate in the design of educational buildings.	Workshop consiting of 1) forming heterogeneous groups, 2) envisioning a participatory design process focused on developing a new educational building and how to involve different stakeholders, 3) presenting the outcomes, and 4) analysing the presentations.	A new Interdisciplinary Model of Participatory Building Design that is based on four workshop propositions of participatory building design processes.

Reference	Research purpose	Analysis / validation method	Main findings
Könings et al. (2011)	Examines participatory design as a strategy for taking student perceptions into account in instructional re/design.	Two quantitative surveys: 1) Inventory of Perceived Study Environment Extended (IPSEE) to measure students' perceptions of a particular learning environment and their desires with regard to the design of that environment. 2) Inventory of Perceived Study Environment Extended-Teacher Version (IPSEE-T) in which some items are reformulated to reflect the teacher's perspective.	The findings indicate that the effects of participatory design on students' perceptions, perceived-desired discrepancies, and teacher–student disagreement show some positive effects for the co-designers, but limited or negative effects for the rest of the class.
Könings et al. (2010)	Develop an approach for student participation in instructional design, and to evaluate how students and teachers experience the discussion about possible changes in the design and how they co-operate in designing lessons.	For evaluating the participatory meeting, the teachers, co-designing students and the remainder of the class were asked open questions about the quality of the meeting and/or the agreement with its proposed changes.	Both teachers and co-designing students were largely satisfied with the meeting. The atmosphere was experienced predominantly as comfortable and enough opportunities were provided to express thoughts and ideas. Teachers stated that the usability of students' suggestions was good. The students predominantly agreed on the proposed changes. No differences were found between the evaluation scores of students of different courses.
Könings et al. (2007b)	Teachers' perceptions of an innovative learning environment "Second Phase"	Inventory of Perceived Study Environment Extended-Teacher (IPSEE-T): teacher's perceptions of a particular learning environment and their desires with regard to the design of a learning environment.	Study showed that the implementation of the innovative learning environment only partly succeeded and that more cooperation between educational designers and teachers is needed to create more congruence between the educational design and the factual learning environment in the classroom.
Lingnau and Lenschow (2010)	How teachers use a computerised learning environment to teach pupils with special educational needs.	Analysing teachers' contributions in a Wikipage that was established for the development project.	The Learning Chest software is an example of a software development process where teachers become proactive contributors. Authors believe that encouraging the teachers to actively participate in the development process was a key factor for the success of the software development.
Lundström et al. (2016)	Examine the relationship between user needs and the service level in construction projects through a case study where a university cafeteria was renovated using a PD method called charrette.	Video observations, project document analysis, and survey questionnaires	1) PD provided a positive impact on the resulting premises, even though every part of the project may not be successful. 2) the accomplishments can be undone in the later phases of the project if collaboration is not extended through the entire project. 3) the study revealed a framework of user needs that can be used in design management in order to enhance the user perspective.

Reference	Research purpose	Analysis / validation method	Main findings
Otero et al. (2013)	Utilising digital public displays to take into consideration educational goals	The findings reported are based on a qualitative data analysis approach where the design team discussed together the data collected and created meaningful interpretations of it.	teachers were able to generate scenarios that take advantage of the possibilities offered by digital public displays to stimulate learning processes. However, there are several crucial elements regarding management and control of content that need to be carefully designed in order to accommodate each schools' organizational issues.
Pantsar-Syväniemi et al. (2015)	Design a situation-aware safety service for children with a unique combination of novel participatory tools, a brainstorming workshop, and scenario writing.	1) brainstortming workshop 2) Open Web Lab to gather people's thoughts and ideas, 3) Service Innovation Corner (SINCO) 4) Scenario writing.	Design process proved to be powerful and enabled the gathering and receiving of valuable feedback from both end users and the local society.
Parsons and Cobb (2014)	Examine the complexity of navigating and involving different user groups in the context of multi-disciplinary research projects.	Derives findings for the research objective by reflecting multiple previous research projects.	Complexity as a triple-decker 'sandwich' representing Theory, Technologies and Thoughts and argue that all three layers need to be appropriately aligned for a good quality product or outcome. The challenge lies in navigating and negotiating all three layers at the same time, including the views and experiences of the learners.
Parsons et al. (2011)	Develop specific interactive technologies for school settings that may help to promote learning and understanding of social skills.	Pilot testing, but not described how these were analysed.	Initial impressions from pilot testing are that both prototypes are motivating and enjoyable to use for typically developing children and children with Autism Spectrum Conditions
Pedersen et al. (2012)	how mathematics teaching can be enriched by apps using smartphone sensors such as gyroscope, compass, camera, and touch screen in a gaming context.	Three user testing iterations.	The application we developed enriched mathematics teaching by introducing several modes of participation: 1) Physical activity in the real world, 2) Individual and collaborative interaction, 3) Gaming elements, 5) Aural and visual feedback, and 5) Social media.
Põldoja et al. (2014)	Addresses design challenges related to a software solution for self- and peer-assessment of teachers' digital competencies.	Four stages: 1) contextual inquiry, 2) participatory design, 3) product design, and 4) production of software as hypothesis. A small-scale validation experiment.	Teachers in the validation experiment were satisfied with Web-based self- and peer-assessment of teachers' digital competencies and how it was implemented in the design of the DigiMina tool.
Pollock and Amaechi (2013)	PD research on texting as a channel for personalized youth support.	Analyzed the texting record during and after the pilot, using basic principles of grounded theory (Charmaz 2006) and thematic coding (Lofland and Lofland 1995).	Text messaging could rapidly deepen student–teacher support relationships, with effects on student–teacher bonding, caring, and student motivation.

Reference	Research purpose	Analysis / validation method	Main findings
Prins et al. (2016)	Presents an activity-based instructional framework that assists educational designers in transforming authentic scientific practices for the population of students in science education.	1) an exemplary version of the curriculum, guided by the initial instructional framework, 2) the pedagogic decisions were conceptualized as design guidelines, 3) the exemplary curriculum unit was piloted in four different classes resulting in a second version, 5) second version was enacted in two different classes and studied in-depth to reveal the experienced coherency in learners, and 6) the results were used to revise and enrich the initial instructional framework, yielding an activity-based instructional framework.	An instructional framework that provides educational designers with a set of prescriptive guidelines for transforming authentic modeling practices into contexts for learning, while maintaining the coherency between scientific activities, content, and tools.
Rahamat et al. (2011)	Develop and evaluate the usability of a web-based learning resource fo the English Literature Component.	Questionnaire of Usability Evaluation of Website (QUEW).	The findings of formative evaluation gave insight into a things needed in developing web-based teaching material.
Rodrigo and Ramírez (2017)	incorporating the use of 'master' online template courses as a part of the initial and continued professional development processes of online TPC instructors.	Authors have been developing and updating the course curriculum for the professional and technical writing (P&TW) traditional face-to-face and newly emerging online class offerings and developing a four-course certificate program in P&TW.	The developed master course can be used as model that new online TPC instructors can use to learn about teaching online and promote the reason to continuously prompt reflection and innovation through a user-focused iterative revision process.
Rodríguez-Triana et al. (2012)	Which aspects should be considered at design in order to monitor the learning scenario.	1) co-design process between teacher and researcher to obtain a monitorable CSCL script, 2) putting the script into practice, 3) results were triangulated with data coming from observations carried out by the teacher during the face-to-face sessions, 4) two questionnaires handed to the students about their work in groups, and 5) and several interviews to the teacher during and after the learning situation.	Three dimensions that influence the configuration of the monitoring process in pattern-based approaches: the design pattern, the specific features of each activity, and the teacher's choices about specific issues.
Santally et al. (2015)	Develop a social partnership model based on the living lab concept to promote the professional development of educators through formal and informal capacity-building initiatives.	Reflections from several projects.	The model tries to embody the new open innovation concepts as proposed by the Living Lab ecosystem and can serve in the longer term as an example for other initiatives.
Selwyn et al. (2017)	explores the possibilities of making existing school data openly available in digitised form for teachers, administrators and students to access, interpret and use.	PD was used as a research methodology to investigate the realities of the two school contexts as places of data use, and to highlight where it might be possible to align more democratically the use of school data with the values, history and context of the whole school community.	PD interventions in both schools quickly encountered compromises and barriers – all of which illustrated the relatively closed nature of school data practices and, it follows, the practical limitations of the open data philosophy.
Siozos et al. (2009)	Identify challenges faced by computer-based assessment (CBA) in secondary education and put forward a framework of design considerations.	1) Multiple iterations of the same concise and highly structured collaborative design session with different students, 2) designers systematically analyze and integrate student products from the different sessions into a final application.	Designing effective CBA applications can be realized by actively involving students and teachers in the design process. Both students and teachers were excited about their participation in the design sessions, and they asserted that they would rely more on educational software designed using this approach.

Reference	Research purpose	Analysis / validation method	Main findings
So et al. (2009)	Design an online platform where teachers can share vivid images of their teaching practices with other teachers.	1) large scale survey to understand current situation 2) describe PD workshops in two schools	Teachers perceived their school culture to be collaborative, but collaboration across schools is rarely encouraged. Most professional development programs are conducted as a pre-packaged format in a face to face mode. Workshop participants expressed that video technology is seldom used in professional development programs, and that there is a strong need to have access to an online video based community for teachers.
Somerville and Collins (2008)	Collaborative planning of library learning commons and campus learning spaces.	Reflects several design projects with various methods.	Inviting and enabling user input from the start offers a fruitful planning approach in which campus librarians, stakeholders, and beneficiaries "learn their way" to appropriate library (re)design decisions.
Song and Oh (2016)	Design of a mobile app-based personal response system	1) interviews, an exploratory evaluation of the prototype using a Likert scale questionnaire.	The participants showed strong agreement with the use of EnClicker increased their enjoyment of lectures and participation level in the questioning activity.
Stephen et al. (2014)	Design of a technology-rich STEM classroom.	Data sources include guided and open-ended interviews with teachers and administrators, student focus groups, and observation of sessions in both the STEM classroom and in regular classrooms. Additional data that inform the study were gathered from survey instruments including pre and post student and teacher questionnaires.	Using a PD process that included students as well as teachers has led to a sense of ownership of the room by both groups. Teachers and students depict traditional classrooms as 'teacher space' while they view the STEM classroom as 'community space' with both teachers and students equally responsible for maintaining the room.
Su et al. (2010)	Investigate the possibility of applying the engagement, exploration, explanation, elaboration, and evaluation model (5E) to science e-learning materials.	Study used triangulation to inspect the data collected from the weekly worker records, written journals and meeting observations for examining documents such as technology standardization and instructional strategy.	The presented results contribute to the integration of 5E learning cycle into SCORM-conformant materials and provide concrete recommendations for how to develop effective e-learning materials in the future.
Tammets et al. (2011)	Examine the applicability of an organizational knowledge-management model extended by the principles of self-regulated learning.	1) A web-based Likert-scale survey, 2) design interview, and 3) evaluation of the service with nine Estonian teachers.	The study showed how to technologically support maintaining and pursuing professionalism through teachers' participation in the community of practice, through collaborative learning and knowledge building activities.
Triantafyllou and Timcenko (2013)	Explores the challenges of integrating digital technologies to support mathematics teaching and learning at university level.	1) prototyping with two professors, 2) focus group discussions with students, 3) group interviews with teaching assistants, and 4) observation of seven lectures.	Professors, teaching assistants and students do not always share same perceptions about how the mathematics curriculum should be taught and which parts of it are challenging. While professors focus on visualizing mathematical concepts, students and teaching assistants stress the importance of focusing on basic mathematics first and also presenting applications of mathematics in Media Technology.

Reference	Research purpose	Analysis / validation method	Main findings
Tulinius et al. (2012)	1) create a link between general practitioner (GP) researchers and the GP training community and 2) create an awareness of critical appraisal in surgeries training GPs, allowing GP trainers to experience the relevance of critical appraisal for their own clinical practice.	1) two 'think tanks', 2) 14 interviews, 3) 119 hours of observations, 4) 583 written evaluation forms, written and oral evaluations, 5) 13 additional interviews.	It was possible to overcome several of the previously reported obstacles in critical appraisal training of GP trainees. However, the study is also an illustration of an inbuilt obstacle to any attempt to build bridges between the clinical world and academia.
Vakil et al. (2016)	Examine how race and power mediate relationships between researchers and communities in ways that significantly shape the process of research.	Using the notion of politicized trust as a conceptual lens, authors reflect on two distinct participatory design projects to explore how political and racial solidarity was established, contested, and negotiated throughout the course of the design process.	Making visible how race and power mediate relationships in design research is critical for engaging in ethical and sociopolitically conscious relationships with community partners and developing theoretical and practical knowledge about the repertoires of practice, tasks, and sociocultural competencies demanded of university researchers.
van Merriënboer et al. (2017)	Addresses the need to align pedagogies and physical learning environments and describes a participatory design process to help to create physical spaces and school buildings that optimally support specific visions on learning and pedagogy.	Reflects the proposed model through two case studies.	Distinguished three phases in such a design process: the specification of a pedagogy, which can be described as an interplay of four basic educational components; the alignment of the chosen pedagogy with seating arrangements and physical learning spaces; and the realisation of the school building.
Woolner et al. (2010)	Explore the views of a diverse sample of individuals from a school community and so develop understanding of the learning environment.	Using visual research methods, authors explored their experiences of the existing school environment together with aspirations for the future, when the school would be rebuilt: 1) photo elicitation, 2) diamond ranking, 3) picture sorting, 4) map-based activities.	Methods facilitated the engagement of a broad range of people from the school community. Furthermore, it was observed that the differing views of those with different roles produced a more complete understanding of the complex functioning of the school and the potential influences of this setting on learning.
Woolner et al. (2007)	Exploring consultation within the modern context of participatory school design and student voice.	1) The teachers completed lesson proformas which investigated the use made of the classroom in terms of layout and lesson structure and perceptions of the quality of the teaching and learning in the session, as well as behaviour management. 2) The teachers were also interviewed by the university team regarding their experiences of the design process.	The message which is heard by designers and architects is no more certain to lead to a complete design solution and still runs the risk of being unrepresentative of the full range of relevant views. The difficulty of deciding whom to consult in order to reveal to architects and designers the needs of education, is not completely solved by emphasizing the involvement of students.
Zainuddin et al. (2010)	Design of an augmented reality book for deaf students.	Ethnographic method via observation to discover what participants thought, their interaction with the researcher, and their reflection on choosing AR-Book sets during the observation and interaction process.	The study identified the criteria in designing an AR-Book for deaf students, which will be used in the prototype development of AR-Book Science in Deaf, called as AR-SiD.

PIII

DESIGN OF A LEARNING SPACE MANAGEMENT SYSTEM FOR OPEN AND ADAPTABLE SCHOOL FACILITIES

by

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Design of a Learning Space Management System for Open and Adaptable School Facilities

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Abstract. In this design-based research project, a learning space management system was developed for the Valteri School Onerva in Central-Finland. The school represents a modern educational environment with open and adaptable learning spaces. The goal was to develop a software to support the stakeholders in organising flexible pedagogical activities and sharing pedagogical practices. To reach this goal, we utilised value-focused thinking as a requirements elicitation method, to identify the objectives that the stakeholders associate with the new environment. In the implementation phase, we organised participatory design workshops, to involve the stakeholders in decision-making, to ensure that the prototype development was proceeding according to their needs. As a result, we elaborate how we utilised value-focused thinking, what were the objectives that were identified, and how they were transformed into system requirements. Finally, we describe the first prototype of the learning space management system, which was developed using these requirements.

Keywords: Classroom Management, Learning Spaces, Educational Technology, Special Education, Value-focused Thinking.

1 Introduction

The traditional classroom setting of children sitting on benches and patiently listening to a teacher is not easily applicable in special education. The classrooms are often considered less inspiring, and an activity-driven approach is more appropriate [38]. For example, children with hearing and vision problems can benefit from visual and physical stimulations and moving between different spaces, and children with autism disorders benefit from the use of technologies and digital artefacts that promote collaborative educational activities and attentional exercises [2]. To overcome these issues, a new school was recently created in Finland, the Valteri School Onerva, which was just finished in early 2016. Its stated goal was to enable functionality, physical activity, and the application of new technologies. The idea of an open and adaptable school was a focus from the planning and construction stages of the school. Under this concept, all physical spaces are understood as potential spaces for learning, not just the classroom, and the environment is dynamically adapted to the needs of the practised pedagogy. A simple example is using stairways as an active learning space: children might physically move from one stairway step to another, while learning the number line, months, or weekdays (Ikkelä-Koski, personal communication, May 5, 2014).

However, the activities in the modern school environment of the Valteri School Onerva must be supported with modern technology. In the stairway example, in a regular educational setting, with the current level of support, it would not be possible to know if the stairway was already in use, as the stairway is a non-traditional learning space and would not be considered by any scheduling tool. The lack of such critical information prevents teachers from implementing such new pedagogical ideas, even simple ones, due to the time costs if the targeted space is not available and the whole class must return to the classroom. Moreover, not all teachers have the time and resources to develop new ideas and surely are not aware of all the available possibilities. Unfortunately, we find the current facility (or classroom) management systems not suitable for use in this dynamic environment. The systems for commercial or non-commercial organisations seem to be developed mainly for standard administrative needs. Instead of traditional facility management features, teachers need a tool that supports them in organising flexible pedagogical activities and sharing pedagogical practices. To successfully develop a learning space management system, we need to carefully examine the objectives that teachers associate with the open and adaptable environment.

As a result, the requirements for a learning space management system were produced in the ONSPACE research project between May 1 and December 5, 2014, before the building construction even started [50]. Requirements elicitation is one of the most critical activities of software development and is known to be a major reason for project failures [39]. We grounded our research in two assumptions: First, to have a better understanding of teachers' work, we needed to involve our stakeholders and arrange user-centred workshops, based on participatory design principles. Participatory design emphasises shared decision-making, which is crucial when different stakeholders are involved [11]. Second, traditional requirements elicitation concentrates on identifying system's goals, functionality, and limitations [39]. While this is fundamental, we argue that the stakeholders' objectives need to be defined more holistically than just considering the actual system. Therefore, we applied a method developed by Professor Ralph Keeney and proposed in the book *Value-focused Thinking: A Path to Creative Decision Making* [22]. The method offers systematic guidelines, which are described in a later section, for identifying objectives for the defined decision problem.

This study has both methodological and practical contributions. Value-focused thinking has been applied in multiple domains, but less in the context of requirements elicitation, especially as they relate to education. Learning space management systems are currently gaining attention as modern schools increasingly adjust to the idea of open and adaptable learning environments [43]. The identified objectives were used during the implementation of the learning space management prototype. To fulfill our goals, we framed the following research questions:

- *How can value-focused thinking be implemented and applied to the requirements elicitation context?*
- *What are the objectives associated with an open and adaptable school environment?*

For the first question, we describe in detail how we applied the method, and for the second, we interpret recordings from the workshops and present the identified objectives, with the help of teachers, administrative personnel and rehabilitation instructors. The original requirements specification document is in Finnish and consists of 32 pages; therefore, its full inclusion is beyond the scope of this paper. Instead, we highlight and discuss the process of extracting the objectives, followed by a discussion of the objectives. The prototype of the system was developed in 2015, in the sequel project called ONSPACE2, and the objectives were used as guiding evaluation principles by software engineers during development of the learning space management system.

2 Towards novel school facilities

Facility management considers assets that are not the primary activity for the organisation, but essential to function [26]. These assets are typically buildings and properties, while information systems, human resources, and finance are understood as separate areas. In education context, assets may include school buildings, accessories, vehicles, and permissions to certain services, like a healthcare specialist or a school psychiatrist. While efficient management of these assets can make a significant difference regarding financial cost and value in any organisation, the physical environment itself, like the school building, can have an enormous impact on facilitating learning [26, 29, 49]. A good physical environment gives resources, inspiration, and motivation for learning. Moreover, the physical environment can be enhanced with virtual properties, by using information technology [25]. The virtual resources can extend the social action, by allowing distant interactions and enabling learning activities for students with perception problems. In addition to physical and virtual aspects, there is a social dimension: how interactions are made possible between people within organisation culture.

Lievonen and Kinnunen [31] point out how information technology extends learning situations beyond school buildings. Therefore, spatial navigation, spatial control, interpersonal communication and collaboration need to be considered. Kumpulainen and Mikkola [28] even argue that learning 21st-century skills, like critical thinking, problem-solving or media literacy, are challenging to promote in an educational environment that is restricted to a particular space and time. They call for learning environments that reconfigure spaces for learning, because there is an increasing number of students who feel disengaged and disconnected from formal education.

The principal stakeholder of this study, the Valteri School Onerva, has utilised modern ideas based on Kuuskorpi's [30] Doctoral Thesis in the construction of their new building. Kuuskorpi defines the dimensions for a physical learning environment as: societal orientation, individual orientation, informal learning processes and formal teaching (Figure 1), and learning spaces can be positioned according to these dimensions. In the Valteri School Onerva, this means that the physical space and its furniture can be adapted to different purposes and the common spaces are made available to various functions.

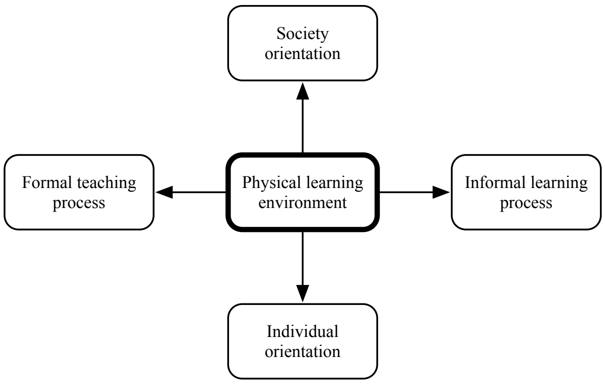

Fig. 1. Dimensions for a physical learning environment [30].

Nevari [37] has designed the concept for the new building, illustrated in Figure 2. The areas are called *parks*, *fountains*, and *dens*. A park is an open space, which can be easily modified for group work, presentations and physical activities. A fountain is a partially open space for collaborative learning, which can be divided into different areas, to suit both formal and informal learning situations. A quiet, individual and closed space is called a den, and it can be used for focusing on a task, individually or in small groups. In addition to the novel concept of physical space, there are no prearranged spaces for teachers or students. The idea is that the learning and working activities will happen in the space that is most suitable at the current moment, instead of staying in classrooms or offices. This idea is the underlying motivation for our study, to develop technology that could give the best support for organising activities in this unique environment.

3 Approaches for user participation and involvement

User participation and involvement are considered essential for success in system development [3, 17, 32], as they improve the quality of the system, by generating more precise requirements [16] and tend to lead

Fig. 2. Concept of the Valteri School Onerva [37].

to a positive attitude and perceived usefulness among users [1, 34]. Participation refers to assignments, activities and behaviours that users engage in during the system development process and involvement is a psychological state of the individual, defined as the importance and relevance of a system to a user [3]. User involvement can also be seen as a broader concept, in which users are somehow involved in the system's development process, whereas user participation refers to more active and intentional involvement [18]. Kujala [27] has presented methodological approaches to achieving participation and involvement (Table 1).

Table 1. Methodological approaches to achieve participation and involvement [27].

Participatory design	**User-centered design**	**Ethnography**	**Contextual design**
Democratic participation	Usability	Social aspects of work	Context of work
Workshops, prototyping	Task analysis, prototyping, usability evaluations	Observation, video analysis	Contextual inquiry, prototyping

In user-centred design, ethnology, and contextual design, participation can be characterised as an approach by the designer to gain information from participants. The fundamental difference in participatory design is that it encourages participants to actively take part in the decision making and creative processing of the solution [11]. The goal of participatory design is not just to empirically understand the design activity (or users, as in user-centred design), but to simultaneously envision, shape, and transcend it to benefit the participants [48].

The ideological grounding of participatory design emerged from Scandinavian workplace democracy, to ensure that people who are affected by technology can also participate in making decisions about it [6, 10, 15, 36]. In participatory design, the following statements are understood as guiding principles: participants from diverse backgrounds are seen as experts in how they live their lives and design in collaboration with other professionals [41, 42], participants have the right to influence technological decisions affecting their private and professional lives [5], and especially, participatory design is seen as appropriate in the context of special needs [4, 12, 14, 33]. Thus, we have based our workshops on participatory design, to adopt these principles, and we have implemented value-focused thinking as a requirements elicitation technique.

4 Value-focused thinking

Value-focused thinking (VFT) comes from the operational research field and has been applied to decision problems in multiple domains, such as defence, environment, energy, government, corporations, and intelligence [40]. The underlying principle of VFT is that, when faced with a decision problem, participants should first examine their *values*. In general, values are core concepts within individuals and society [51]. Values are desirable and trans-situational goals that serve as principles that guide one's lives [13, 44]. Keeney [22, 23] employs values as principles for evaluation of actual or potential consequences of action or inaction, of proposed alternatives, and of made decisions. In VFT, decision makers reflect what they want to achieve, instead of immediately comparing alternative solutions. Values, moreover, can be made explicit for examination, by associating them with a specific statement of objectives, which are in the form of a verb, followed by an objective [22, 24].

The basic steps of the VFT process are as follows: develop a list of values, convert values to objectives, and classify them, as a means-ends objective network [46, 47]. The starting point is the statement of the problem to be solved. The definition of the problem must be made carefully, to ensure a shared understanding of the situation. Participants are asked to make a list of anything that they hope to achieve, by solving the problem being addressed. This is done without any restrictions or constraints in reflection, to reach the different dimensions that participants find valuable. After generating the initial list, participants are encouraged to extend the list, by using different mind-probing techniques (Table 3 in [23]). For example, participants can be asked to review each item and articulate why they care about it, which in turn might lead to new items. This phase of producing a comprehensive list requires intensive thinking and discussion, and it will most likely take several iterations.

The list is considered as completed, when participants cannot find any new information about the problem. Then, each list item is translated into the format of objectives (Keeney defines this phase as converting values into a common form). For example, if the participants expressed that the school day is too busy, the item might be *"rush"*, and the objective would be *"reduce rush"*. This might raise a discussion, for instance, on why there is rush and how it could be reduced. This, in turn, may generate new items and objectives. Finally, the list needs to be examined for possible redundancies, which have to be eliminated.

The next phase is to classify objectives as *fundamental* - or *means objectives*. Fundamental objectives characterise the essential interests in the decision situation, representing the goals that participants value. Means objectives are of interest due to their implications for the degree to which fundamental objectives can be achieved. For example, if reducing rush is a fundamental objective, the respective means objectives could be about having the needed accessories available. Finally, the structure of these objectives is illustrated, by building a *means-ends network*, which demonstrates how the different objectives are related to each other. The process of structuring objectives results in a deeper and more accurate understanding of what one cares about and helps to clarify the decision context and enhances the quality of decisions [23].

5 Methodology

5.1 The stakeholder organisation

The Valteri School Onerva is one of the six learning and consulting centres for Valteri schools that operate under the Finnish National Board of Education. The school provides services that support learning and school attendance, in order to implement general, intensified, and special support. In the school, education is combined with rehabilitation and guidance that support learning, to form a seamless whole. The school has expertise particularly in supporting needs relating to vision, hearing, language, and interaction. The school's mission is to increase the accessibility of support services and promote the neighbourhood school principle. The school aims to realise this, by making their operations more effective, creating new action models and innovations, and utilising new technology. The aim is to develop solutions for learning and rehabilitation that support learning for individuals. The school's activities are guided by a development-oriented approach and the utilisation of research and networking.

5.2 The data gathering process

To gather the data for the extraction of our requirements rooted in the theory as explained above, we have organised four workshops (Table 2) in collaboration with the school's staff. The data was collected by recording the workshops with a video camera or mobile phone; the researchers also took notes. The participants were special education teachers, occupational therapists, visual sense specialists, and researchers. The researchers who participated in the workshops were all from the University of Jyväskylä, Faculty of Information Technology. There was some variation between workshops: in the first workshop there was one person from the technical staff, and in the last workshop, there were two members of the instructional staff, but otherwise, the membership stayed constant. All of the workshops were held in the old school's facilities, to help researchers understand the context at the given time and provide teachers and staff members with familiar surroundings.

Table 2. Value-focused thinking workshops [50].

1.	14.5.2014	8 teachers, 1 technical staff, 3 researchers	Video
2.	24.8.2014	6 teachers, 4 researchers	Video
3.	27.9.2014	6 teachers, 3 researchers	Audio
4.	12.12.2014	6 teachers, 2 instructors, 3 researchers	Video

The first workshop acquainted the participants with one another and familiarised everyone with the context of our study. Informal group discussions were conducted, during which we asked questions about the plans for the new school building, elicited their ideas of an open and adaptable environment, and discussed the initial needs for the learning space management system. The technical staff member presented a three-dimensional (3D) model of the new school building, and researchers analysed it, together with the participants. The researchers produced conceptual maps of the building, to gain a better understanding of the new environment. Finally, the participants discussed the initial desired functions and the possible users of the system.

In the second workshop, the participants were asked to provide ideas that they considered important for the open and adaptable environment. This triggered intensive discussions, which resulted in a list of words (items) which described anything that the participants perceived as valuable in the school context. The list was reviewed and discussed again, and the participants were asked to classify these 'raw' words, by defining higher level categories to encompass all of them. Finally, the participants transformed the items into objectives, which represented their shared understanding of how each item could be achieved. Next, the objectives were examined as a whole, with the goal of removing redundancy and disentangling abstract objectives, transforming them into more concrete ones. The emerging objectives were scrutinised again, by asking the participants *"why is this item important?"*. The goal of this iterative, cyclical process was to encourage more elaboration of the objectives, as well as good grounding and justification for each emerging objective, and finally, good placement in the overall context. Because time was limited during the workshop itself, the participants were asked to finish the task by themselves afterwards, and they sent the final document by email to the researchers.

5.3 Extracting functional requirements

The analysis of the first two workshops was based on the VFT methodology. First, the recordings were checked, to ensure that there was no missing data, and to verify the notes the researchers took during the discussion. The resulting document then included a full list of objectives. When analysing the objectives, we found that some of them were directly related to the actual system, whilst others related to the whole organisation. Therefore, the objectives were divided into two categories: system objectives and organisational objectives. From the system objectives, we derived the requirements that defined the initial functions of the system and illustrated them as a use case diagram. Every use case was then described in use case scenarios, which detailed how the user interacts with the system.

In the third workshop, the researchers described to participants how the use case diagram were constructed and how the system would be used, by describing the use case scenarios. Furthermore, the researchers presented initial user profiles, system architecture, and non-functional requirements. The participants then discussed the requirements and gave feedback on how they could be enhanced. After the workshop, the requirements were updated, based on the feedback from the participants. The final version of the document was sent to the participants two weeks before the final meeting, in December 2014. In the last meeting, participants evaluated the outcomes and validated the produced requirements. The participants appreciated the transparency of the design process and how researchers were able to communicate using language they understood. Finally, researchers thanked the participants for their collaboration and discussed future plans for the prototype development.

5.4 Identifying objectives

The recordings of the four workshops were transcribed completely, in order to gain an overall view of the data, which were then exported into the ATLAS-ti software, for a more detailed interpretation. Data was analysed through a process of open coding [9], to develop a list of utterances that are related to the objectives of the group, that is, what the group considered important, or the way they thought that the desired situation could be achieved. All 153 utterances were examined one by one and assigned at least one code. The coding process was overlapping: a single utterance could be connected to many different codes and vice-versa. If it was impossible to connect an utterance with any of the previous codes or imagine a new code, the utterance was removed as an irrelevant phrase. Finally, 133 utterance remained that had been assigned at least one code. The rejected utterances were examined again, to ensure that no relevant data was removed by chance or mistake.

The utterances inside the codes were refined, to ascertain that the codes had a coherent structure. The codes, including the assigned utterances, were analysed, to differentiate between fundamental objectives and means objectives. If the assigned utterance expressed an essential objective, it became a candidate for a fundamental objective. If the assigned utterance expressed something that was important because of its implications for some other objective, it was a candidate for a means objective. Finally, the transcriptions were read through again, to validate the structure of the objectives.

6 The resulting objectives

The fundamental objectives regarding an open and adaptable environment were identified as follows: improving communication, strengthening the community, increasing efficiency, enabling functionality, taking special needs into account, and ensuring privacy (Table 3). These are further discussed one by one. Each of these fundamental objectives were allocated means objectives, in order to bring these objectives closer to the actual implementation. Moreover, means objectives were further classifed into *organisational means* and *technological means*. Organisational level means represent the social actions that contribute towards the fundamental objective. System level means were defined as those features of the system that could possibly contribute to an associated fundamental objective.

Table 3. Summary of identified objectives: fundamental objectives and means objectives (organisational and technological).

Fundamental objective	Organisational means	Technological means
Improve communication	Communication culture; Discuss conflicting reservations;	Access with mobile devices; Automatic conflict handling; Information about reserved spaces; Purpose for reservations; Owner of a reservation;
Strengthen community	Responsible use of resources; Negotiated rules and norms; Open discussion;	A "right of way" feature; Reservation status;
Increase efficiency	Planned behaviour;	Visual information; Real-time information; Usability; Mobile use;
Enable Functionality	Think differently; Functional pedagogy; Creative use of spaces;	Recommends suitable spaces; Shows accessories; Shows the purpose of a space; Shows size of a space; Accessible from different locations and with different devices
Pedagogical use	Empower students; Guide to responsive use of ICT;	Authentication policy; Generic student accounts; Take account of special needs; Accesible user interface;
Ensure privacy and security	Respect privacy of others;	Critical information on dedicated servers

6.1 Improved communication

The first fundamental objective regarded improved communication. The hope was that teachers, staff, and students would not be isolated in the classrooms and this would encourage more communication between people. We thus interpreted communication as a central objective, even though it often appeared implicitly in the data, because it is strongly connected to other objectives. For example, the connection with privacy appears as a need to have spaces available for private conversations between teachers, students, and other stakeholders. Participants emphasised that, regardless of the features or possibilities of the system, there is a need for a culture of open communication. It is unavoidable that conflicts will occur when adjusting to a new environment. Participants agreed that the responsibility for solving conflicts cannot be outsourced entirely to technology. Even when a mechanism for automatically resolving reservation-related conflict would exist, the prioritisations policy must be determined by the people.

Communication can be improved in many ways at the system level. The primary feature required was that the system could be accessed by mobile devices. The participants stressed that they do not have time to look for a desktop computer during the day. One proposition was that there could be tablet devices ported near the learning spaces, making it easy to check the status of the space and make a reservation. The participants brought up the issue that information related to reservations needed to be easily accessed and needed to contain some mandatory fields: contact information of the person who made the reservation and the purpose of the reservation. From a pedagogical perspective, there should also be features allowing for commenting, rating and sharing knowledge about the learning possibilities of spaces.

6.2 Strengthened community

A strong community was conceptualised as a situation wherein the whole school community is able to negotiate shared goals among stakeholders and work together towards them. As discussed before, the participants emphasised the need for a culture of open communication. The participants concluded that they needed to learn ways to co-operate in an open and adaptable environment: the actions are less confined to classrooms, and possible conflicting encounters need to be negotiated. It is not just the policies and rules that need to be negotiated with the school staff, the whole operational culture of the school needs shifting.

The participants proposed an interesting feature for the system, which was named *"right of way"*. The idea was that the system could understand if someone had privileges to certain spaces and automatically reorganise the reservations, based on these privileges. This raised an intense discussion about what constituted privileges and whether this idea conflicted with the open and adaptable environment. Moreover, this feature would be rather complicated to implement, technically.

An essential method of strengthening the community was found to be the possibility of marking reservations with open or closed status. An open reservation means that the space is reserved for certain people, but others are still welcome to use it at the same time. Some spaces are divided into smaller rooms or areas, which could be used in parallel. For example, two classes of deaf children, communicating via sign language, could share the same room, as long as they would use the separating curtains available in the room. This feature was appreciated by the participants, because it further supported the idea of collaboration and more efficient use of facilities.

6.3 Increased efficiency

The participants extensively discussed how everyday life would be organised in the new environment. The idea of not having their own classrooms was both fascinating and frightening. The main expectation from the technological tool was that it would help to organise the school activities. This is a crucial issue and affects the whole work community, as one teacher commented: *"I think, it [the system] would help to sort things out, without unnecessary hassle. It is something that would have a great impact on our work atmosphere"*. We interpret that time is the most limited resource the participants have, and it is extremely important that using the developed technology does not waste it. The participants also emphasised how the ability to plan activities beforehand will make the working day more tranquil.

When considering the actual system, the participants described that efficiency was about getting real-time information that could be used everywhere and that was easy to use. They also noted the possibility of having visual information. A concrete example of the relationship between ease of use and efficiency being discussed was based on their previous experiences with a facility management system which had a complicated function for removing reservations and resulted in too many *"no-show"* reservations. A visual view (visual interface) of the building was important for the participants. They were used to perceiving the dimensions of the new building on the map. The possibility of making reservations with a visual picture was thought to be more accessible than, for example, a list of available spaces. Mobile access was again mentioned, because it supported the idea of an open and adaptable environment, by encouraging people to move around.

6.4 Enabling functionality

The participants shared the view that action-based learning has a very important role in special education; therefore, enabling functionality is one of the main goals of the open and adaptive environment, and so, it seemed rather self-evidently to qualift as a functional objective. Functionality was conceptualised as a vision where activities are always happening in the space that is most suitable for the intended pedagogical practice and that is available at the current moment. The participants hoped that a more functional environment would lead to more creative pedagogy, due to the possibilities the new learning spaces are offering. However, creativity was seen as a challenge: how to question the old practices (and think differently) and pedagogically combine the needs of the students and new learning spaces?

The main question at a system level was what spaces are made available for reservation. There seemed to be contradictory views between the new way of understanding all spaces as *"open learning spaces"* and the need for individual and private spaces for certain tasks. This discussion resulted in interesting observations; for instance: if there is a room with several workstations, does the reservation apply to the whole room, or is it possible to reserve only a single workstation? Solving these issues led to a clearer understanding of the level on which the decisions are made: between people, pre-programmed in technological systems, or as institutional policies. According to the participants, the following features of the system would enable functionality: the system is able to recommend the most suitable spaces based on certain criteria, it is easy to see important information in the system, and the system can be accessed from any location in the school, with most used devices.

6.5 Pedagogical use

The students of the school have a wide range of special needs. Different perceptional abilities present a challenge between the creative and dynamic use of learning spaces and the need for structure and formality. For example, it is essential for blind students to learn how to navigate through the building and find the necessary accessories inside the learning spaces on their own. The school introduced several guides for this, including typical tracks for blind people, but also innovative uniquely textured walls, which helped identify the respective spaces, as well as a novel sound-based guidance system (specific intersections emitting different little tunes, to be uniquely identifiable).

The participants, however, discussed that the world itself is not structured for the needs of blind people, and an important aim is to teach students to act independently outside the school. This reflects the idea that using the system should be one way to facilitate the students' independence. The system was seen as an opportunity to enhance responsibility, by empowering students to reserve learning spaces for themselves and by guiding students towards responsible use of information and communication technology (ICT). The participants noted that permitting students to use the system could result in accidental or intentional misuse, but they seemed to agree that, despite the possible unwanted scenarios, it is important to accustom students to ICT.

An important issue was to decide on user policies and authentication within the system. One possibility was to create user accounts for every student, but this would raise challenges related to security and technical implementation. Information related to students has high-security classification, which would mean tight restrictions in the system. The participants proposed the possibility of making generic user accounts for students, so their personal information could not be revealed. Special needs were to be taken into account in system development, to make pedagogical use of the system possible.

6.6 Ensuring privacy and security

An important matter of discussion was how privacy could be ensured in the open and adaptable environment. The participants emphasised the need for private spaces, to have conversations with stakeholders and how this privacy needs to be respected. They also commented that visual positioning information about staff or students could be very useful, but that it raises many privacy-related problems. However, participants explained that they have actually had emergency situations during which a student has been completely lost.

From a technical perspective, the discussion focused around how the current technological infrastructure is connected to the system and what security vulnerabilities it might cause. The participants concluded that critical student information is stored in dedicated servers and that access to the system should be restricted.

7 The resulting learning space management system prototype

In order to implement the objectives that resulted from the VFT workshops, firstly, the researchers created a use-case diagram. This use case diagram of the prototype is presented in Figure 3. The functions within *Onspace mobile* are optimised for mobile devices (responding to the fundamental objective of increased efficiency, via the technological means of 'mobile use', as well as the fundamental objective of enabling functionality, via the technological means of accessibility from different locations and via different devices). The administration functions *Onspace web* are only available from the administrative interface (responding to the fundamental objective of ensuring privacy and security, viathe technological means of having critical information on dedicated servers).

These two different interfaces reflect the fact that the prototype allows for two user roles: user and admin(istrator). In addition to the user functions, the administrator can edit all reservations, user information, and learning spaces. The server functionality is developed with the Django Web framework, the PostgreSQL open source database, and HTTP servers Nginx and Gunicorn. The user interface is built on a variety of open source Javascript libraries.

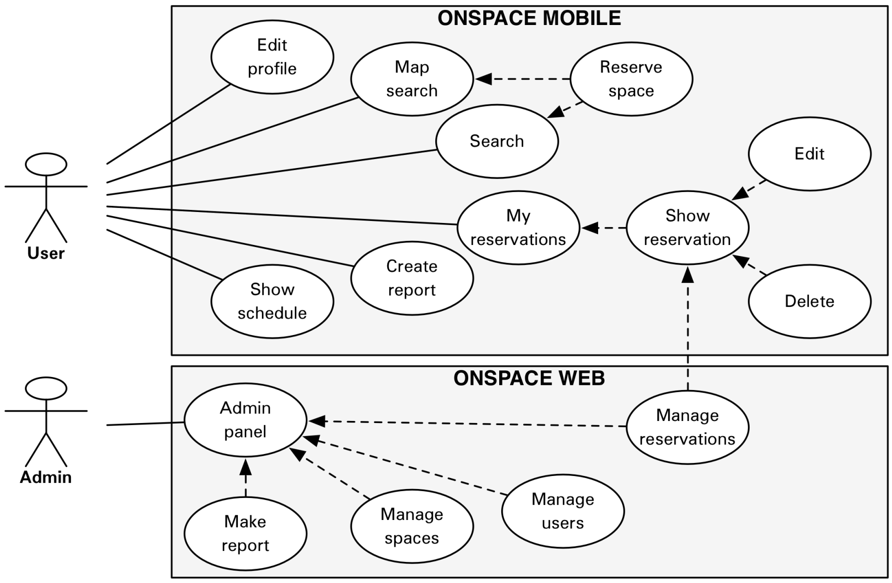

Fig. 3. Use case diagram.

The main use scenario, user logging in and making a reservation with the map-based interface, is presented in Figure 4: 1) The user logs in with his credentials. 2) The prototype automatically assigns the current date and the next rounded half hour as the starting time for a reservation and displays the first floor of the building. If the user changes the parameters, the map under the search view is immediately updated. 3) The map shows the areas in the single floor of the building and how many free learning spaces the area has. 4) The user chooses the area C from the first floor and can now see the map of the area, which has currently four available learning spaces. 5) The user clicks on the desired learning space, and the reservation model opens. The learning space information includes a description and the accessories it has. The user can write the purpose of the reservation and needs to choose whether the reservation is open or closed for other people. 6) The user can see all the reservations as a list or on a calendar. The reservations can be edited and removed, by clicking.

7.1 Prototype development and additional participatory design workshops

The prototype implementation was carried out by the first author and a project researcher during May - December 2015. During the development phase, we organised another set of monthly participatory design workshops (Table 4). The first meeting included mainly decision-making stakeholders, such as the Head of the School, and was focused more on project practicalities, such as timetables, responsibilities, and contracts. The school's ICT staff manager was also present, to describe the current technical infrastructure. We agreed to develop a responsive web application that could be used by different computers and mobile devices, due to the fact that the school staff uses a broad range of mobile devices, from different manufacturers.

Table 4. Participatory design workshops during the implementation stage.

Initiation	17. June, 2015
1. workshop	27. August, 2015
2. workshop	17. September, 2015
3. workshop	21. October, 2015
4. workshop	19. November, 2015
Final meeting	17. December, 2015

The workshops represented iterative cycles of negotiation, development, and demonstration. The participants of the workshops were: special education teachers, occupational therapists, visual sense specialists, researchers, and developers - similar to the set of design workshops, which defined the initial set of objectives. This allowed for them to follow the transformation of their objectives into practical features of a running software system. The implementation had a modular nature, in order to be able to add features in an incremental way, as well as to easily rectify individual features, based on the workshop feedback from the participants. Every workshop began with an explanation on what features we had been working on since the previous workshop. Then, the problem was approached with different techniques: by presenting questions, having group discussions, and using a sketching tool. Feedback from the workshop helped in refining the features and deciding on priorities. The prototype was ready by the end of 2015. In the final meeting, the prototype was presented and validated. We made an agreement that the developers will produce a documentation for the school's ICT staff and help them with technical issues. This enabled the school to continue the development of the prototype, according to any further needs. This was made especially easy by the modular approach of our implementation, which allows further extensions, based on the growing needs of the school.

8 Discussion

The design process described is an example of re-imagining a rather typical information management system, but for a completely new environment, represented by the open and adaptable school. It was clear from the beginning that we needed to reinvent the characteristics of facility management systems. In practice, we needed to encourage the participants to reflect on the new surroundings and their everyday work, to frame what was important to them and to clarify what they wanted to achieve. To reach this

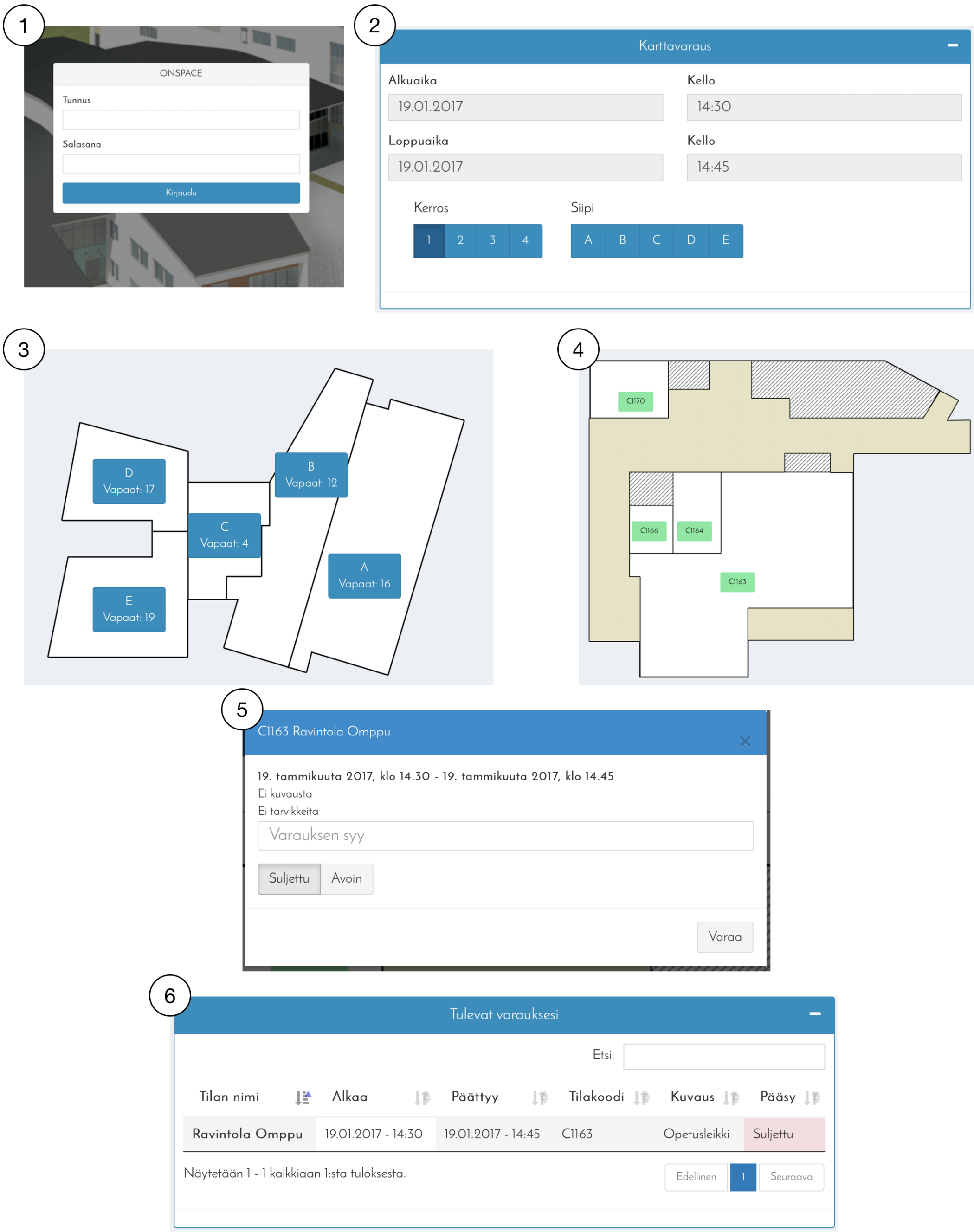

Fig. 4. Use case of logging in and making a reservation.

goal, we organised four workshops, during which we applied value-focused thinking, to identify objectives for a learning space management system for an open and adaptable environment.

Our utilisation of value-focused thinking had two stages: first, we needed to analyse the workshops from the perspective of requirements specification, in order to establish necessary attributes of the system - that is, functions, a use case diagram, and use case scenarios. After the workshops, we made a more in-depth investigation of the data, using an open coding analysis. This two-staged analysis was used to verify our results. As Morse et al. [35] state, data may demand to be treated in different ways, so the analytic procedure should match the research questions. The first analysis stage was more practical and straightforward, while the second stage required a more reflective strategy and critical discussions about the project, between the authors of this paper.

The fundamental objectives identified were, as described above: improving communication, strengthening community, increasing efficiency, enabling functionality, pedagogical use of the system, and ensuring privacy and security. These fundamental objectives, as well as the means to achieve them, are described at a system - as well as at an organisational level. We argue that this approach helped and will help developers, in general, to take a more holistic view in the development phase. The functions and features of the system need to be considered together with organisational level means, and they should be in line with approved fundamental objectives. The results render a more in-depth representation about the context, people, and environment for which the system is developed.

We implemented a prototype of the system and involved our stakeholders in monthly participatory design workshops. The participants had a real opportunity to influence the prototype development and there was strong collaboration between researchers and participants. Researchers were able to learn about the work and the new environment of the participants and the researchers were able to share knowledge about technical possibilities, as well as restrictions. The workshops were advantageous, because the stakeholders continuously discussed the underlying philosophy of the new school and how the prototype should support it. The concept of the *"old way"* was used to describe the traditional school, where teachers have their own classrooms and learning activities are pre-programmed in timetables. The prototype that supports the *"new way"* would enable the dynamic and creative use of learning spaces and prevent teachers from returning to the habit of reserving a single space for extensive periods of time. This method additionally helped the developers to understand the most important objectives and optimise their resources to meet then.

We also collided with various issues during the design process. VFT does not put emphasis on the complex power relationships participants may have. The method assumes that people are able to communicate their thoughts, regardless of the social hierarchies that may constrain the discussion. Furthermore, VFT examines the identified objectives as a whole, while the objectives between different stakeholders might be very conflicting. The question is, whose objectives are we supposed to meet? As an example, the requirements did not include a feature to make recurring reservations. However, when the implementation phase was ending, the administrative staff was disappointed, because of the lack of that feature. They need to rent certain assets for other organisations and the contracts are made for long time periods, and manually inputting and updating these reservations with the prototype would be an arduous task.

Furthermore, the rationale of VFT is that decision-making is based on the values of decision makers, rather than just comparing possible alternatives. The concept of value is very challenging, because of the different definitions of value in different research fields and even among individuals. Keeney's [22, 23] definition is very general, and the difference between the concepts of value and objective is not completely clarified. To underline the point, for some people, value is about currency or efficiency and for others it is about ethical questions. As an anecdote, Cockton [7, 8] changed the name of the concept from value to worth after struggling with the same issue. It may seem appealing to use a pre-defined set of values, as in Schwartz's [45] theory of basic values, which provides more depth to the contents and structure of values, but as Isomursu et al. [20] discussed, using a pre-defined framework to analyse and interpret the findings can lead to confirmation bias.

Even if we embrace Keeney's definition, the question arises of how to reach abstract constructions that may be difficult to form as statements. For example, Iversen et al. [21] pointed out that values are not static entities that are waiting for researchers and developers to collect them, but more like changing, complex and abstract ways of being and thinking. Keeney seems to take it for granted that decision makers are automatically people who are able to express what is important to them. For example, when designing with children, there should be more appropriate methods than just asking *"what it is that one cares for"*. People's values tend to emerge, change and even conflict, and researchers should carefully consider who is answering these questions and what they mean.

9 Conclusion

In this paper we have described how the objectives for a learning space management system for a very special type of adaptive school were identified with the value-focused thinking method and how the system prototype was developed. We find it of utmost importance to understand the participants as a human agents, with intentions, feelings, and attitudes, instead of contenting ourselves with a generic definition of users with shared goals [18, 19]. Different stakeholders consider the confronted design problems from their own perspectives and it needs to be acknowledged that the goals of the stakeholders can conflict. Concludingly, we found value-focused thinking as an applicable method, allowing for a holistic approach to requirements elicitation. However, at the same time, we found that more focus on the different stakeholder roles is needed. We have implemented a system prototype which instantiates the identified objectives. However, more data is needed to investigate the outcomes of the developed system prototype and the impact of using value-focused thinking.

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References

1. Abelein, U., Paech, B.: Understanding the influence of user participation and involvement on system success – a systematic mapping study. Empirical Software Engineering 20(1), 28–81 (feb 2015), `http://link.springer.com/10.1007/s10664-013-9278-4`
2. Alessandrini, A., Cappelletti, A., Zancanaro, M.: Audio-augmented paper for therapy and educational intervention for children with autistic spectrum disorder. International Journal of Human-Computer Studies 72(4), 422–430 (apr 2014), `http://linkinghub.elsevier.com/retrieve/pii/S10715819`
3. Barki, H., Hartwick, J.: Measuring user participation, user involvement, and user attitude. MIS Quarterly 18(1), 59–82 (1994)
4. Benton, L., Vasalou, A., Khaled, R., Johnson, H., Gooch, D.: Diversity for design. In: Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14. pp. 3747–3756. ACM Press, New York, New York, USA (2014), `http://dl.acm.org/citation.cfm?id=2556288.2557244http://dl.acm.org/citation.cfm?doid=2556288.2557244`
5. Bergvall-Kåreborn, B., Ståhlbrost, A.: Participatory design: one step back or two steps forward? In: Proceedings of the Tenth Anniversary Conference on Participatory Design 2008. pp. 102–111 (2008)
6. Bjerknes, G., Bratteteig, T.: User participation and democracy: a discussion of Scandinavian research on system development. Scandinavian Journal of Information Systems 7(1), 73–98 (1995), `http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.91.6452{\&}rep=rep1{\&}type=pdf`

7. Cockton, G.: Value-centred HCI. In: Proceedings of the Third Nordic Conference on Human-Computer Interaction - NordiCHI '04. pp. 149–160. ACM Press, New York, New York, USA (2004), http://dl.acm.org/citation.cfm?id=1028038http://portal.acm.org/citation.cfm?doid=1028014.1028038
8. Cockton, G.: Designing worth is worth designing. In: Proceedings of the 4th Nordic Conference on Human-Computer Interaction Changing Roles - NordiCHI '06. pp. 165–174. No. October, ACM Press, New York, New York, USA (2006), http://portal.acm.org/citation.cfm?doid=1182475.1182493
9. Corbin, J.M., Strauss, A.: Grounded theory research: Procedures, canons, and evaluative criteria. Qualitative Sociology 13(1), 3–21 (1990)
10. Ehn, P.: Work-Oriented Design of Computer Artifacts. Ph.D. thesis, Umeå Universitat (1988), http://www.diva-portal.org/smash/record.jsf?pid=diva2:580037{\&}dswid=-8358
11. Frauenberger, C., Good, J., Fitzpatrick, G., Iversen, O.S.: In pursuit of rigour and accountability in participatory design. International Journal of Human-Computer Studies 74, 93–106 (feb 2015), http://dx.doi.org/10.1016/j.ijhcs.2014.09.004http://linkinghub.elsevier.com/retrieve/pii/S1071581914001232
12. Frauenberger, C., Good, J., Keay-Bright, W.: Designing technology for children with special needs: bridging perspectives through participatory design. CoDesign 7(1), 1–28 (mar 2011), http://www.tandfonline.com/doi/abs/10.1080/15710882.2011.587013{\%}5Cnhttp://dx.doi.org/10.1080/15710882.2011.587013
13. Friedman, B.: Value-sensitive design. Interactions 3(6), 16–23 (dec 1996), http://portal.acm.org/citation.cfm?doid=242485.242493
14. Guha, M.L., Druin, A., Fails, J.A.: Designing with and for children with special needs. In: Proceedings of the 7th International Conference on Interaction Design and Children - IDC '08. p. 61. ACM Press, New York, New York, USA (2008), http://dl.acm.org/citation.cfm?id=1463719http://portal.acm.org/citation.cfm?doid=1463689.1463719
15. Halskov, K., Hansen, N.B.: The diversity of participatory design research practice at PDC 2002–2012. International Journal of Human-Computer Studies 74, 81–92 (feb 2015), http://linkinghub.elsevier.com/retrieve/pii/S1071581914001220
16. Harris, M.A., Weistroffer, H.R.: A new look at the relationship between user involvement in systems development and system success. Communication of the Association for Information Systems 24(1), Article 42 (2009)
17. He, J., King, W.R.: The role of user participation in information systems development: implications from a meta-analysis. Journal of Management Information Systems 25(1), 301–331 (jul 2008), http://search.ebscohost.com/login.aspx?direct=true{\&}db=buh{\&}AN=33245055{\&}lang=de{\&}site=ehost-livehttp://www.tandfonline.com/doi/full/10.2753/MIS0742-1222250111
18. Iivari, J., Isomäki, H., Pekkola, S.: The user - the great unknown of systems development: reasons, forms, challenges, experiences and intellectual contributions of user involvement. Information Systems Journal 20(2), 109–117 (mar 2010), http://doi.wiley.com/10.1111/j.1365-2575.2009.00336.x
19. Isomäki, H.: The Human Modes of Being in Investigating User Experience, pp. 191–207. Springer London, London (2009), http://dx.doi.org/10.1007/978-1-84800-385-9_10
20. Isomursu, M., Ervasti, M., Kinnula, M., Isomursu, P.: Understanding human values in adopting new technology - a case study and methodological discussion. International Journal of Human-Computer Studies 69(4), 183–200 (2011), http://dx.doi.org/10.1016/j.ijhcs.2010.12.001
21. Iversen, O.S., Halskov, K., Leong, T.W.: Values-led participatory design. CoDesign 8(2-3), 87–103 (jun 2012), http://www.tandfonline.com/doi/abs/10.1080/15710882.2012.672575
22. Keeney, R.L.: Value-focused thinking: a path to creative decisionmaking. Harvard University Press, Cambridge, Massachusetts (1992)
23. Keeney, R.L.: Value-focused thinking: identifying decision opportunities and creating alternatives. European Journal of Operational Research 92(3), 537–549 (aug 1996), http://www.sciencedirect.com/science/article/pii/0377221796000045http://linkinghub.elsevier.com/retrieve/pii/0377221796000045
24. Keeney, R.L.: Identifying, prioritizing, and using multiple objectives. EURO Journal on Decision Processes 1(1-2), 45–67 (jun 2013), http://link.springer.com/article/10.1007/s40070-013-0002-9http://link.springer.com/10.1007/s40070-013-0002-9
25. Keppell, M., Riddle, M.: Distributed Learning Spaces: Physical, Blended and Virtual Learning Spaces in Higher Education. In: Physical and Virtual Learning Spaces in Higher Education, pp. 1–20. IGI Global (2012), http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-60960-114-0.ch001

26. Kok, H.B., Mobach, M.P., Omta, O.S.: The added value of facility management in the educational environment. Journal of Facilities Management 9(4), 249–265 (2011), http://www.researchgate.net/publication/235297138{\%}5CnThe
27. Kujala, S.: User involvement: a review of the benefits and challenges. Behaviour & Information Technology 22(1), 1–16 (2003)
28. Kumpulainen, K., Mikkola, A.: researching learning across space and time in extended learning environments (2014)
29. Kumpulainen, K., Rajala, A.: Negotiating time-space contexts in students' technology-mediated interaction during a collaborative learning activity. International Journal of Educational Research (2015) (2015), http://dx.doi.org/10.1016/j.ijer.2016.05.002
30. Kuuskorpi, M.: Future physical learning environment. User oriented exible and changeable teaching spaces. Dissertation, University of Turku (2012), http://www.doria.fi/bitstream/handle/10024/76724/vaitoskirja2012Kuuskorpi.pdf
31. Lievonen, M., Kinnunen, P.: Main features of an ideal learning space: A user-based description. In: Proceedings of the 6th Annual Architectural Research Symposium in Finland. p. 8 (2014), http://ojs.tsv.fi/index.php/atut/article/download/47183/13933
32. Mahmood, A.M., Burn, J., Gemoets, L., Jacquez, C.: Variables affecting information technology end-user satisfaction: a meta-analysis of the empirical literature. International Journal of Human-Computer Studies 52(4), 751–771 (apr 2000), http://linkinghub.elsevier.com/retrieve/pii/S1071581999903531
33. Malinverni, L., MoraGuiard, J., Padillo, V., Mairena, M.a., Hervás, A., Pares, N.: Participatory design strategies to enhance the creative contribution of children with special needs. In: Proceedings of the 2014 Conference on Interaction Design and Children - IDC '14. pp. 85–94. ACM Press, New York, New York, USA (2014), http://dl.acm.org.libgate.library.nuigalway.ie/citation.cfm?id=2593981{\&}CFID=469514897{\&}CFTOKEN=53769239http://dl.acm.org/citation.cfm?doid=2593968.2593981
34. McGill, T., Klobas, J.: User developed application success: sources and effects of involvement. Behaviour & Information Technology 27(5), 407–422 (sep 2008), http://www.tandfonline.com/doi/abs/10.1080/01449290601110715
35. Morse, J.M., Barrett, M., Mayan, M., Olson, K., Spiers, J.: Verification strategies for establishing reliability and validity in qualitative research. International Journal of Qualitative Methods 1(2), 13–22 (2002), https://ejournals.library.ualberta.ca/index.php/IJQM/article/view/4603
36. Muller, M.J., Kuhn, S.: Participatory design. Communications of the ACM 36(6), 24–28 (jun 1993), http://doi.acm.org/10.1145/153571.255960
37. Nevari, J.: Oivaltamo: avautuva oppimistila. Ph.D. thesis, Lahti University of Applied Sciences (2013)
38. Özen, A., Ergenekon, Y.: Activity-based intervention practices in special education. Educational Sciences: Theory and Practice 11(1), 359–362 (2011)
39. Pacheco, C., Garcia, I.: A systematic literature review of stakeholder identification methods in requirements elicitation. Journal of Systems and Software 85(9), 2171–2181 (2012), http://dx.doi.org/10.1016/j.jss.2012.04.075
40. Parnell, G.S., Hughes, D.W., Burk, R.C., Driscoll, P.J., Kucik, P.D., Morales, B.L., Nunn, L.R.: Invited review-survey of value-focused thinking: applications, research developments and areas for future research. Journal of Multi-Criteria Decision Analysis 20(1-2), 49–60 (jan 2013), http://dx.doi.org/10.1002/mcda.442http://doi.wiley.com/10.1002/mcda.1483
41. Sanders, E.B.N., Brandt, E., Binder, T.: A framework for organizing the tools and techniques of participatory design. In: Proceedings of the 11th Biennial Participatory Design Conference. p. 195. PDC '10, ACM Press, New York, New York, USA (2010), http://portal.acm.org/citation.cfm?doid=1900441.1900476
42. Sanoff, H.: Special issue on participatory design. Design Studies 28(3), 213–215 (may 2007), http://www.sciencedirect.com/science/article/pii/S0142694X07000178
43. Sanoff, H., Walden, R.: School environments. In: The Oxford Handbook of Environmental and Conservation Psychology, pp. 276–294 (2012), http://oxfordhandbooks.com/view/10.1093/oxfordhb/9780199733026.001.0001/oxfordhb-9780199733026-e-15
44. Schwartz, S.H.: Universals in the content and structure of values: theoretical advances and empirical tests in 20 countries. Advances in Experimental Social Psychology 25(C), 1–65 (1992)
45. Schwartz, S.H.: An overview of the schwartz theory of basic values. Online Readings in Psychology and Culture 2, 1–20 (2012)

46. Sheng, H., Nah, F., Siau, K.: Strategic implications of mobile technology: a case study using value-focused thinking. The Journal of Strategic Information Systems (2005), http://www.sciencedirect.com/science/article/pii/S0963868705000405
47. Sheng, H., Siau, K., Nah, F.F.H.: Understanding the values of mobile technology in education. ACM SIGMIS Database 41(2), 25 (may 2010), http://dl.acm.org/citation.cfm?id=1795380http://portal.acm.org/citation.cfm?doid=1795377.1795380
48. Spinuzzi, C.: The methodology of participatory design. Technical Communication 52(2), 163–174 (2005), http://www.ingentaconnect.com/content/stc/tc/2005/00000052/00000002/art00005
49. Todhunter, B.J.: An examination of the views of key stakeholders on the development of learning spaces at a regional university. Journal of Facilities Management 13(2), 204–222 (2015), http://www.emeraldinsight.com/doi/abs/10.1108/JFM-06-2014-0016
50. Tuhkala, A., Isomäki, H., Hartikainen, M., Cristea, A., Alessandrini, A.: Identifying Objectives for a Learning Space Management System with Value-focused Thinking. In: Escudeiro, P., Costagliola, G., Zvacek, S., Uhomoibhi, J., McLaren, B. (eds.) Proceedings of the 9th International Conference on Computer Supported Education (CSEDU). SCITEPRESS - Science and and Technology Publications, Porto, Portugal (2016)
51. Williams, R.M.: Change and stability in values and value systems: A sociological perspective. Understanding Human Values: Individual and Societal Values 1, 5–46 (1979)

PIV

TECHNOLOGY COMPREHENSION – SCALING MAKING INTO A NATIONAL DISCIPLINE

by

Tuhkala Ari, Wagner Marie-Louise, Nielsen Nils, Iversen Ole Sejer, and Kärkkäinen Tommi 2018

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Technology Comprehension - Scaling Making into a National Discipline

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ABSTRACT

We account for the first research results from a government-initiated experiment that scales Making to a national discipline. The Ministry of Education, in Denmark, has introduced Technology Comprehension as a new discipline for lower secondary education. Technology Comprehension is first experimented as an elective subject in 13 schools. The discipline combines elements from computing, design, and the societal aspect of technology and, thus, resonates with the existing FabLearn and Making initiatives in Scandinavia. We report the identified opportunities and challenges based on interviews, surveys, and a theme discussion with experienced teachers from the 13 schools. The main takeaways are: First, the teachers did not perceive Technology Comprehension as a distinguished discipline, which calls for more research on how Making is scaled into a national discipline. Second, Technology Comprehension opens up for interdisciplinary and engaging learning activities, but teachers need scaffolding and support to actualise these opportunities. Third, Technology Comprehension challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs. Teachers need pedagogical means to take the societal aspect into account within the discipline. Finally, we argue for further research on supporting teachers when scaling Technology Comprehension on a national level.

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technology comprehension; computational thinking; design; education; teachers; national; scaling; making; discipline

INTRODUCTION

We present the opportunities and challenges of scaling *Making* into a nationwide discipline, which is called as *"Technology Comprehension"* (translated from *"Teknologi Forståelse"*, hereafter referred as TC). The new discipline is initiated by the Danish Ministry of Education and will be incorporated into the national lower secondary education curriculum (13-15 y.o. students). TC comprehends three main learning objectives: Students understand the core concepts in computing, such as programming, algorithms, pattern recognition, and abstraction. Students specify and articulate a problem and utilise an iterative design process to develop a digital solution. Students reflect and evaluate the problem solution, its applicability, impact, and ethical concerns, from the societal perspective. During the implementation of the new discipline, we conducted interviews, surveys, and a theme discussion with teachers from 13 Danish secondary schools to investigate how the discipline is actualising and what opportunities and challenges the teachers perceive. For this purpose, we address two research questions: **How is Technology Comprehension perceived as a discipline by experienced teachers** and **what opportunities and challenges teachers face when introducing TC in lower secondary education?**

Making considers hands-on activities, collaboration, prototyping, and iterative design to create digital and physical artefacts and to promote self-cultivation and democratisation [2, 31, 4, 5, 33]. Thus, Making is strongly connected with previous research on design of technology and learning activities with children [34, 30, 19, 27]. Much of the research, that is carried out particularly under the concept of Making, examines opportunities and challenges of Making activities in out-of-school context [36, 29]. However, more research in formal education context is emerging [3, 17, 8, 35, 13]. Hence, our study contributes to reseach in formal education context by scaling Making into national policy level through TC.

TC is inspired by extracurricular activities in Denmark, such as Fablab at School [32], Coding Class [16], and Coding Pirates [25]. Consequently, we consider TC as a Scandinavian alternative for CS4all[1], Code.org[2], and the curriculum defined by the Computer Science Teacher Association[3]. These are heavily grounded on *computational thinking*, which was made popular by [40], and later clarified by [1] as: *"thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms"*. In national educational policies, such as in the United Kingdom, computational thinking is positioned as a necessity for students' future careers [37]. In contrast, TC combines computing, design, and a societal aspect as an interdisciplinary discipline, where the learning goals are understood as means, instead of end-goals, to engage creatively in technology development, understand the role of technology in society, and critically reflect the role of technology in one's life.

The paper reads as follows: Section 2 overviews the current research about Making in formal education context. Section 3 presents the goals and learning objectives of TC, as defined by the Danish Ministry of Education. Section 4 describes the research context, research questions, and the data collection and analysis methods. We present and discuss the findings in sections 5 and 6. Finally, we conclude the findings, present the limitations, and propose further research.

MAKING IN EDUCATION

Making has gained a lot of attention in recent years [4, 21, 26, 22]. *Making* refers to the process of adopting a *"maker mindset"* through the creation of meaningful, significant, and shareable artefacts [15, 22]. Maker mindset relates to the definition of *technologically fluent*: developing adaptive skills in technology and computation to empower people to manipulate the medium to their advantage and to handle unexpected problems [24]. Making manifests Dewey's democratisation, Papert's constructionism, and Freire's critical pedagogy by incorporating democratisation and empowerment into classical learning-by-doing approaches, such as project-based, student-centred, and constructionist learning [4].

The possibilities of Making are recognised in education context. [21] argues that Making provides opportunities to interact with concrete objects-to-think-with, link students' personal interests and learning activities, and develop self-efficacy through affecting the surrounding environment. [4] states that Making provides an environment for working in a design process with an interdisciplinary approach. [22] proposes that Making provides sophisticated tools for students to build and think and a tolerant environment for experimenting, play, and making errors. [8] found that students acquired, through scaffolding, sufficient technical skills, mental models related to troubleshooting and problem decomposition, and understanding the possibilities and practices of sharing ideas and responsibilities.

Despite the opportunities, unfolding Making is challenging due to the incompatibility between obscure processes and the formality of educational settings [32, 33]. [17] point out that teachers need to be able to navigate a complex process, manage digital and analogue materials, and balance different modes of teaching. [33] emphasise understanding Making technologies as reflective tools instead of outcomes, developing language to express the quality in Making, and creating means to handle insecurity, contingency, and possible lack of authority. Consequently, teachers are too often left alone after the first stage of introducing Making for schools [5].

[13] examined a national level distributed Makerspace project as a single case study by using thematic analysis of a set of heterogeneous material. They summarise five main considerations: Procurement practices to identify tools, materials, and kits in partnership. Teacher and leader perspectives emphasizing professional training and knowledge sharing with mutual understanding between teachers and school leaders. Informing national policy-making to support general management, for example, of joint teaching material and curriculum development. Creating equal opportunities on both Making and computing for both genders, especially for girls. And finally, creating initial interest, later supported by knowledge creation, through challenging and more advanced projects.

Despite the previous findings, research on Making in the formal education setting is still scarce [3, 15, 22]. Furthermore, a great extent of studies considers Making in the STEM, Computer Science, or Natural Sciences [2, 14, 35, 36]. Only a few studies have examined Making in an up-scaled version, which reaches beyond a municipality or a school district [13, 6]. Hence, there is a crucial need for examining Making as a part of an established and nationwide discipline.

TECHNOLOGY COMPREHENSION

The Danish Ministry of Education initiated TC as a new discipline for lower secondary education. The curriculum was formulated by three experts representing teaching and research. TC was first piloted in 13 schools as an elective course during fall 2017. The teachers, who are assigned to teach TC, had not received supplementary or in-service training to teach the discipline. Between summer 2018 and 2021, TC will be experimented in over 40 schools to investigate three implementation options: *i*) an independent subject running from first to ninth grade, *ii*) an integrated discipline to existing subjects or *iii*) combination of both, where TC is integrated into other subjects between first to sixth grades and then as an independent subject from third to ninth grades.

The ministry [11] has defined four mandatory topics that TC needs to address: *i*) The implications of technology and au-

[1] CS4All, www.cs4all.io, retrieved 14.3.2018

[2] Code.org, code.org, retrieved 14.3.2018

[3] Computer Science Teacher Association, www.csteachers.org, retrieved 14.3.2018

tomation on society, including an understanding of security, ethical and consequences of digital technologies. *ii*) Computing as a knowledge area, including basic knowledge of networks, algorithms, programming, logic and algorithmic thinking, abstraction and pattern recognition, data modelling as well as testing. *iii*) Iterative design process as an interaction between gaining an understanding of the world that is being designed to and gaining an understanding of the digital technologies that are being designed with. *iv*) Complex problem solving, where children create new digital solutions and, hence, learn to argue for their relevance through an understanding of design processes.

The ministry [12] has also defined three learning objectives for TC: *i*) Students learn to produce and analyse digital products. *ii*) Students learn to develop, modify, evaluate and refine digital products through work with remixing, refinement, and production. *iii*) Students learn the possibilities and role of informatics as a catalyst for changes in society, in order to strengthen the capabilities for acting in a meaningful way in a democratic and digital society, including constructive and critical contribution in shaping the digital society.

TC has some intersections with computational thinking and computational concepts, practices, and perspectives [40, 7, 20]. However, TC differs significantly from computational thinking in the following areas: Firstly, it treats computing and design as equal competency areas. Secondly, these two areas are dependent on each other, in order to develop students' capabilities to analyse, design, and develop digital products. Thirdly, it integrates the societal aspect, meaning the critical reflection of the societal impact of technology, as a part of the learning objectives. In this sense, TC is related to [31]'s *"Bildung"*, as a way of considering complex and sustainable learning. These three standpoints are all related to, but different from similar initiatives, such as CS4all in the United States, CoolThink in Hongkong, and Computing in the United Kingdom.

METHOD

The research is carried out as a co-financed research project, in collaboration between the Center for Computational Thinking and Design at Aarhus University and the Danish Ministry of Education, initiated in October 2017 (Figure 1). The overall goal is to investigate whether TC is appropriate for Danish lower secondary education. The research centre will develop support for the projects' schools and teachers, in order to pursue successful implementation of TC. This support includes establishing an understanding of professional competencies of TC and facilitating peer support among the teachers. Thus, the research perspective is focused on teachers' perceptions.

During winter 2017, we familiarized with the study context by conducting semi-structured interviews with 14 teachers, by following classroom activities of TC in 12 schools, and by sending a survey about the support that teachers would need [23]. Based on these preliminary investigations, we defined the following research questions: *i*) "How is Technology Comprehension perceived as a discipline by experienced teachers" and *ii*) "What opportunities and challenges teachers face when introducing TC in lower secondary education?"

Figure 1. Specifications of TC in lower secondary education.

- Trial period from 2017 to 2020
- 13 public schools in Denmark, selected by the Ministry of Education to represent different geographical areas and socio-economic diversities
- 20 teachers and 303 students in the first year of the project
- In 2019, 45 schools will have TC as a compulsory program
- In 2021, TC will be compulsory for K-9 students

Table 1. Participants' teaching background ($n = 18$)

#	Subjects	Teaching experience
Workshop 1 - Aarhus		
1	IT pedagogy	over 10
2	Math, physics, chemistry, history	3-5
3	History, societal, physics, chemistry, IT	over 10
4	Math, physics, chemistry, TC	over 10
5	Languages, math, sports, household, nature and technology	3-5
6	Math, sports, IT/Fablab	over 10
7	Math, nature and technology, religion, crafts and design, TC	over 10
8	Danish, music, fablab	over 10
9	Math, nature and technology, science	over 10
Workshop 2 - Copenhagen		
10	English, history, crafts and design	5-10
11	Nature and technology, TC	0-2
12	Music, english, TC	0-2
13	Danish, religion, sports, music, TC	0-2
14	History, religion, nature and technology, biology	0-2
15	Math, physics, chemistry, TC	5-10
16-18	Unknown	unknown

We designed a six-hour workshop to provide support for the teachers and to collect data for the study. At the beginning of the workshop, we informed all participants about the data collection. The workshop was executed two times at different regions of Denmark, once in Aarhus (19th February, 2018) and once in Copenhagen (21st February, 2018). In Aarhus, there were nine participants from seven schools: eight teachers and one pedagogical consultant. In Copenhagen, we also had nine participants, of which seven were teachers and two school principals (Table 1).

Our first research question holds the assumption that the workshop participants have previous knowledge and expertise in TC related contents, even though they have not received specific training for teaching TC. Thus, we needed to validate this assumption. We designed a self-assessment questionnaire and provided it to the teachers at the beginning of the workshop. The questionnaire consisted of four Likert scale question sets [9]. To find how the participants perceive their competence in using digital tools in education, we accustomed the first question set from the digital competence model [28]. The digital competence model does not consider programming, thus, the second question set examined participants perceived programming skills. Two final question sets examined the participants' perceived capability to teach design and computing related concepts.

Answers to the Likert scale questions were analysed with IBM SPSS Statistics. First, *"I don't know"* answers were excluded as missing answers. Then, frequencies, frequency distributions, and portions were calculated. The question sets were combined into four Likert scale constructs to calculate the means and standard deviations. However, the internal consistency of the constructs could not be verified, due to the small sample size. We also compared the two workshops using the Mann-Whitney test and found no statistically significant differences.

The qualitative data consisted of open questions in the self-assessment survey and a theme discussion during the workshop. The open questions were about learning methods, positive or negative experiences, needed skills, and contents of TC. The theme discussion was arranged within the workshop and it served as our main data source. The topics of the theme discussion were: What is TC as an elective course for you, how do you incorporate TC in your current teaching, how do you perceive the competence goals, and what should TC be in future? For the theme discussion, we supplied the participants with a handout of TC learning objectives. The discussion was moderated by one of the authors and recorded with two video-cameras.

The theme discussion was translated and transcribed into English because all authors are not fluent in Danish. To answer the research questions, we conducted a collaborative content analysis [9]. First, we negotiated the high-level objective of the analysis. Then, we watched the discussion on a video and made individual notes. After watching the video, we discussed different interpretations and constructed themes that answer the research questions. Finally, we went back to the answers in the self-assessment survey and further developed the themes.

RESULTS

We start by describing the competency of the participants and then continue by reporting the findings for the research questions.

Participants' perceived competency

15 participants answered the self-assessment questionnaire. As can be found in Table 1, seven participants had more than ten years, four participants had three to ten years, and four participants had less than two years of teaching experience. The participants had taught the following subjects: TC, Math, Physics, Chemistry, History, Crafts and Design, Social studies, IT, Danish, Sports, Fablab, Nature and Technology, Religion, German, Music, Biology and Food Literacy.

The participants perceived their competence to use digital tools in education high (Table 2). 90.7% of the answers to the five questions were either competent or highly competent. As mentioned earlier, the digital competence model does not include questions about computing skills. In programming competence questions, Almost all (14) participants answered that they had at least some competence with visual programming languages, such as Scratch. On the other hand, most of the participants (10) had no competence in programming with text-based language. This reveals that, while the participants considered themselves as digitally competent, most had expertise only in using visual programming language. We also asked how the participants perceive their competence to teach TC concepts. Over 60% of the answers to teaching the design concepts were at least competent. In contrast, only 31.1% were at least competent in computing concepts. Consequently, the participants perceived their competence to teach design concepts higher than computing concepts.

Besides the presented competencies, it is worth noting that two of the participants had been part of the expert group in Danish Ministry of Education, which had formulated the exact competency areas, competency goals, proficiency goals and knowledge goals for TC. As a conclusion, the participants perceived high digital competence and most of the participants had a lot of teaching experience and from a broad range of subjects. The participants considered themselves more competent in teaching design concepts than computing concepts.

Participants' perceptions of TC as a discipline

Two of the Danish Government's implementation options positions TC as an individual discipline. Despite this, the participants addressed TC as a part of some other subject. For example, a participant reduced TC as mere programming or other separate skill: *"We created programming and math course that starts in the first grade and runs through all grades. Programming is okay, but should not be a standalone subject, it should be part of the other subjects. A tool."* Likewise, when the participants discussed TC in the context of integrating it into other subjects, they considered TC as a tool for learning other subjects' content: *"I think a lot about how it can be part of the natural science subjects. Currently, I am also teaching crafts, where I think that it could fit in. But, as I said, I also think that having it as a part of the natural science would be very exciting for me."* This also became apparent when the participants talked about the tasks that they involve the students in, as noted by a participant: *"they [students] created math games."* Another participant had integrated other subjects, such as entrepreneurship, into TC: *"I tend to focus on the Design part of the subject because that is what I find awesome, this entrepreneurship and I try to keep asking the students questions if they claim that they are done 'Design a Logo', 'Find a company name', 'Create a business model'."* As a conclusion, these perceptions indicate that the participants lacked formalised ways of addressing TC as a distinct discipline, as explicitly coined by one of the participants: *"This new thing that is starting, I think about it as part of the existing subjects."*

As indicated by the previous examples, the participants explicated mainly episodic knowledge of TC. The participants' arguments derived from their own, or others, practices of using technology in education. Even when the learning goals of TC were handed out to the participants, the arguments manifested personal beliefs, experiences, and interests. When considering the learning objectives of TC, the participants with design background emphasised design goals, participants with computing background computing goals, and participants with humanistic background societal goals. Thus, the participants

Table 2. Perceived competencies of the participants (n = 15).

		1	2	3	4	Σ	Mean	SD
Digital competence	f	0	7	26	42	75	3.47	.48
5 questions	f/n (%)	0.0	9.3	34.7	56.0	100		
Programming competence	f	18	13	9	2	42	1.93	.64
3 questions	f/n (%)	40.0	28.9	20.0	4.4	93.3		
Teaching design concepts	f	3	11	27	1	42	2.62	.60
3 questions	f/n (%)	6.7	24.4	60.0	2.2	93.3		
Teaching computing concepts	f	27	30	28	2	87	1.76	.68
6 questions	f/n (%)	30.0	33.3	31.1	2.2	96.6		

Scale: 1=not competent, 2=little competent, 3=competent, 4=highly competent

did not have a mutual understanding what TC is currently, or what it should be in the future, but instead relied on personal preferences and episodic knowledge.

Opportunities of TC

Most of the discussed opportunities were confused with technology-supported education. The participants referred to examples how technology can support students: *"I can have students that are creating a paper booklet, and right next to them another group that works with creating a blog. Both make equal sense. Then you do have students that are able to concentrate for more than 25 minutes because you have access to different technologies."* Another example was using technology to engage students with special needs: *"I had an experience, where mother of a dyslexic child contacted me. Usually, when the girl had to make presentations, she was embarrassed by doing it. She used the computer to make the presentation and felt more capable of presenting due to the auto-correction tools."* In addition, the participants brought up the opportunity to motivate students, who use digital tools in spare time or to concretise abstract topics, such as perceiving the coordinate system using Scratch.

The participants presented several narratives how TC engages different students. For example, a participant said: *"We have had some boys that were very hard to engage in other subjects, that have been very engaged and therefore also very cooperative on this matter."* This was followed up by an example in special education context: *"I have never gotten them to focus for more than 25 minutes, now they have been working for 90 minutes"*. In general, the participants agreed on the fact that TC is an engaging discipline, as concluded by a participant: *"[TC] is fun, and a lot of students get engaged by it."*

A recurring theme was that TC opens up for more student-centred learning. A participant elaborated on the 9th graders' sense of ownership towards making Math games to 1st graders: *"We were making math games with Scratch, it was obvious that older students had a sense of ownership to this assignment. The 9th graders were supposed to make a math game for 1st graders. The day before, 9th graders used their lunch break to go 1st graders and check if the level was too hard. Then 9th graders went back and adjusted the games. That's very uncommon to 9th graders to do something like that in own time."* This was also exemplified by another participant, highlighting how TC integrates topics that are relevant to students: *"My focus is to have a starting point that the students can relate to, for example, in the Odense municipality we are establishing the new light-rail. The students were concerned about what if a blind person should cross the light-rail, can we be sure that the train will stop. So they tried to build some censors with Micro:bits. This was the classical problem-solving setting that the students could relate to."* These examples demonstrate the opportunity to actualise TC as a design process that integrates computing, the societal aspect, and problem-solving.

As illustrated by the previous quotes, the participants appreciated the fact that TC combines computing, design, the societal aspect, and problem-solving together. They pointed out that, normally, computing-related curricula are designed by people with the computing background. Hence, the learning objectives tend to address mere computing goals. TC opens up for holistic discipline goals when it is designed by stakeholders from various disciplines.

Challenges of TC

Several challenges emerged from the data. The participants' conceptions indicated uncertainty about the meaning of the societal aspect in TC. The participants discussed the societal aspect primarily as a means to contextualise the subject with real-world problems. They referred to topics that were familiar from previous teaching experiences in other subjects, such as *"fake news"* in social media, election meddling, and the earlier example about the light-rail track in Odense. Thus, the participants considered the societal aspect of TC as a means to contextualise classroom activities, instead of a learning objective as such.

The participants proposed students' varying skills as a major challenge. A participant told that: *"I have some boys in my elective course and even before I started the teaching they had downloaded the files we should use. At the same time, I had a girl who did not know what a file is. The students had very different skills for participating in this field."* Another participant noted that if TC is first introduced in seventh grade, the prerequisites of the subject are necessarily low. Otherwise, lack of basic skills, such as basic computer use, will prevent those students to pursue the actual learning goals: *"I would like to be better at presenting the students with a problem as a starting point, where they can analyse, design and develop. Currently, they have mostly worked with learning the different technologies."*. A participant concluded that if the basic computing skills are to be taught in TC, it leaves less space and time for other learning objectives.

Another challenge was that students have different needs regarding the structure and guidance of TC learning activities. Some students want to be challenged and to be provided with less guidance, while others are incapable of acting without clear structure and instructions: *"Some of them expect to be challenged, some of them expect to get everything served on a silver plate. That is one of the biggest challenges I have to get them to be better."* This indicates that TC, as a new discipline, calls for high level of individual differentiation of the learning activities.

Finally, other identified challenges were: gender issue, teachers' need for time and peer support. As manifested by the earlier quotes about students' varying skills, gender issue is an existing topic also in TC. A participant stated: *"A lot of students want to participate in 4-6th grade, in 7-9th grade, it is primarily boys."* The participants' conceptions distinguished between boys, as being interested and knowledgeable, and girls as not necessarily interested, or engaged, in TC. The participants pointed out that teachers need more time, peer support, and scaffolded teaching instructions to be able to implement TC as a new discipline. As concluded by one participant: *" [TC] is a new subject and a new way of thinking in primary school. It requires more preparation time than the 'normal subjects', where you can adopt a lot of existing teaching material from various learning portals into your own work."*

DISCUSSION

Our findings derive from the first year of scaling TC into a national initiative. Despite the fact that we are early in the project, the teachers provided us with important practice-based knowledge for scaling TC and, thus, to our research questions: How is TC perceived as a discipline by experienced teachers and what opportunities and challenges teachers face when introducing TC in lower secondary education? Consequently, our empirical findings suggest that: *i*) teachers do not perceive TC as a distinguished discipline, *ii*) TC opens up for interdisciplinary and engaging learning activities, and *iii*) TC challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs.

Teachers do not perceive TC as a distinguished discipline. Technology Comprehension is a term coined by the Ministry of Education and, thus, not well-known among teachers or in research. Our research results reveal that teachers do not see TC as a distinct discipline, but rather as a set of skills that can be integrated into other disciplines. This finding can be related to what [33] considered as the impediments to integrating making into K12-education. Whereas [33] found that teachers generally lack a sufficient understanding of digital technology and complex problem solving, our study indicates that teachers do not possess an understanding of the disciplines (computing/design/societal aspect) related to digital technology. The insufficient understanding of the disciplines is not a challenge to the teachers, but rather, it is a challenge to the entire TC initiative and ultimately to research.

TC opens up for interdisciplinary and engaging learning activities. As stated above, TC has similarities with current research incorporating computing and design into curriculum based and formal education [32]. We found that teachers identified several opportunities in implementing TC: it encourages children to be creative with digital technology, to work with authentic and complex problems and to take responsibility for their learning process. Moreover, the participants thought that students perceive TC learning activities as engaging, inspiring, and fun. TC shares [31]'s reasons for introducing making in curriculum-based education: developing skills related to computing and computational thinking, but also to digital citizenship, in relation to a digitized and post-modern society. In this way, TC embraces digital competencies as well as critical and reflective personal skills that relate to [31]'s "Bildung", Iversen et al. (2018, in press) Computational empowerment, [4]'s empowerment, and also [7]'s and [20]'s computational perspectives. The opportunities to address digital technology from a critical and societal point of view are discussed by the teachers. However, the teachers do not feel capable of bridging between hands-on activities and more abstract discussion of computational perspectives. To fulfil the opportunities, scaffolding activities such as in-service training of teachers, development of textbook material, and online resources are required to support this effort.

TC challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs. We identified the following challenges: lack of shared understanding of the meaning of the societal aspect in TC, students' varying skills and needs, and paradox between instructional structure and freedom, and lack of girls' involvement. The challenge of balancing between creative Making activities and formal education's structure is already known in research considering Making in education [32, 33, 17]. Furthermore, some of the challenges, such as the need for teachers' support to use digital tools and to teach computing concepts, students' varying skills, and gender issues, are well known in other fields [39, 18, 38, 10]. Our study contributes by pointing out the imminent need for considering how the societal aspect, including topics like ethics, empathy, responsibility, and accountability, are defined as concrete learning objectives to provide teachers with tools to assess how they are being met.

CONCLUSION

This study contributed to the FabLearn community by reporting the first research results from the government-initiated research about introducing Technology Comprehension into a national curriculum. Based on interviews, surveys, and theme discussion with highly experienced teachers, we found that teachers do not perceive TC as a distinguished discipline, TC opens up for interdisciplinary and engaging learning activities, and TC challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs.

We identify the following shortcomings in our study: Our findings derive solely from interactions with teachers and does not include principals, policy-makers, or students. We have not taken into consideration that many teachers will ultimately teach TC without prior experiences or any compulsory education in TC. This will inarguably further emphasise the need for better means to support teachers. Due to the scope of this paper, we have not conducted an in-depth and systematic literature review that goes beyond the recent literature in Fablearn and Making. A next step would be to systematically survey on literature within Computer Science Education, Technology Design with Children, and other relevant research communities to identify what could be gained from similar studies in these areas of research.

The challenges of implementing the political agenda to offer TC to all students in Denmark, even by the highly experienced teachers, should be addressed merely as a general lack of research about TC. Consequently, our study raises several questions for researchers within Fablearn and Making fields: What is TC as a discipline and how do we merge previous research on computing and design education to develop TC? How do we develop a curriculum and supplementary training for pre-service and in-service teachers to support their TC teaching practices? How do we incorporate the critical and societal approach of TC as concrete learning objectives, of which accomplishment could be assessed? How do we balance between the obscure structures of Making, computing, and design with the formal curriculum in education?

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REFERENCES

1. Alfred V. Aho. 2011. Ubiquity symposium: Computation and Computational Thinking. *Ubiquity* 2011, January (jan 2011), 1. DOI: http://dx.doi.org/10.1145/1922681.1922682
2. Douglas Ball, Colby Tofel-Grehl, and Kristin A. Searle. 2017. Sustaining Making in the Era of Accountability: STEM Integration Using E-Textiles Materials in a High School Physics Class. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 2, 7 pages. DOI:http://dx.doi.org/10.1145/3141798.3141801
3. Alexander Berman, Brittany Garcia, Beth Nam, Sharon Chu, and Francis Quek. 2016. Toward a Making Community of Practice: The Social Aspects of Elementary Classroom-Based Making. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 9–16. DOI: http://dx.doi.org/10.1145/3003397.3003399
4. Paulo Blikstein. 2013. Digital Fabrication and 'Making' in Education: The Democratization of Invention. In *FabLabs: Of Machines, Makers and Inventors*, J. Walter-Herrmann and C. Buching (Eds.). Bielefield: Transcript Publishers, 1–21. DOI: http://dx.doi.org/10.1080/10749039.2014.939762
5. Paulo Blikstein and Dennis Krannich. 2013. The makers' movement and FabLabs in education. In *Proceedings of the 12th International Conference on Interaction Design and Children - IDC '13*. ACM Press, New York, New York, USA, 613. DOI: http://dx.doi.org/10.1145/2485760.2485884
6. Susanne Bødker, Christian Dindler, and Ole Sejer Iversen. 2017. Tying Knots: Participatory Infrastructuring at Work. *Computer Supported Cooperative Work (CSCW)* 26, 1-2 (feb 2017), 245–273. DOI: http://dx.doi.org/10.1007/s10606-017-9268-y
7. Karen Brennan and Mitchel Resnick. 2012. New frameworks for studying and assessing the development of computational thinking. *annual American Educational Research Association meeting, Vancouver, BC, Canada* (2012), 1–25. DOI:http://dx.doi.org/10.1.1.296.6602
8. Sharon Lynn Chu, Francis Quek, Elizabeth Deuermeyer, and Rachel Martin. 2017. From Classroom-Making to Functional-Making: A Study in the Development of Making Literacy. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 3, 8 pages. DOI:http://dx.doi.org/10.1145/3141798.3141802
9. Louis Cohen, Lawrence Manion, and Keith Morrison. 2013. *Research methods in education*. Routledge.
10. M. J. Cox. 2013. Formal to informal learning with IT: research challenges and issues for e-learning. *Journal of Computer Assisted Learning* 29, 1 (feb 2013), 85–105. DOI: http://dx.doi.org/10.1111/j.1365-2729.2012.00483.x
11. Danish Ministry of Education. 2018a. Kommissorium for den rådgivende ekspertskrivegruppe for forsøgsprogram for styrkelse af teknologiforståelse i folkeskolens obligatoriske undervisning. (2018). https://www.uvm.dk/-/media/filer/uvm/udd/folke/pdf18/jan/180124-kommissorium-for-raadgivende-ekspertskrivegruppe-teknologi pdf
12. Danish Ministry of Education. 2018b. Teknologiforståelse valgfag – Fælles mæl og læseplan. (2018). https://www.emu.dk/modul/teknologiforst
13. Eva Eriksson, Carl Heath, Peter Ljungstrand, and Peter Parnes. 2017. Makerspace in school—Considerations from a large-scale national testbed. *International Journal of Child-Computer Interaction* (2017), 1–7. DOI: http://dx.doi.org/10.1016/j.ijcci.2017.10.001
14. Deborah A. Fields, Yasmin B. Kafai, Tomoko Nakajima, and Joanna Goode. 2017. Teaching Practices for Making E-Textiles in High School Computing Classrooms. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 5, 8 pages. DOI: http://dx.doi.org/10.1145/3141798.3141804
15. Michail N. Giannakos, Monica Divitini, and Ole Sejer Iversen. 2017. Introduction for the Special issue on 'Maker technologies to foster engagement and creativity in learning'. *Entertainment Computing* 18 (jan 2017), 143–144. DOI: http://dx.doi.org/10.1016/j.entcom.2016.11.001

16. Mikala Hansbøl and Stine Ejsing-Duun. 2017. Hovedrapport: Coding Class - Documentation og Evaluering. (2017). https://itb.dk/sites/default/files/Rapport

17. Mikkel Hjorth, Rachel Charlotte Smith, Daria Loi, Ole Sejer Iversen, and Kasper Skov Christensen. 2016. Educating the Reflective Educator: Design Processes and Digital Fabrication for the Classroom. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 26–33. DOI: http://dx.doi.org/10.1145/3003397.3003401

18. Shihkuan Hsu. 2017. Developing and validating a scale for measuring changes in teachers' ICT integration proficiency over time. *Computers & Education* 111 (aug 2017), 18–30. DOI: http://dx.doi.org/10.1016/j.compedu.2017.04.001

19. Netta Iivari and Marianne Kinnula. 2016. Inclusive or Inflexible: A Critical Analysis of the School Context in Supporting Children's Genuine Participation. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI '16)*. ACM, New York, NY, USA, Article 63, 10 pages. DOI: http://dx.doi.org/10.1145/2971485.2971531

20. Yasmin B. Kafai, Eunkyoung Lee, Kristin Searle, Deborah Fields, Eliot Kaplan, and Debora Lui. 2014. A Crafts-Oriented Approach to Computing in High School: Introducing Computational Concepts, Practices, and Perspectives with Electronic Textiles. *Trans. Comput. Educ.* 14, 1, Article 1 (March 2014), 20 pages. DOI: http://dx.doi.org/10.1145/2576874

21. Eva-Sophie Katterfeldt, Nadine Dittert, and Heidi Schelhowe. 2015. Designing digital fabrication learning environments for Bildung: Implications from ten years of physical computing workshops. *International Journal of Child-Computer Interaction* 5 (sep 2015), 3–10. DOI: http://dx.doi.org/10.1016/j.ijcci.2015.08.001

22. Lee Martin. 2015. The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research (J-PEER)* 5, 1 (apr 2015). DOI: http://dx.doi.org/10.7771/2157-9288.1099

23. Sharan B. Merriam. 2009. *Qualitative Research - A Guide to Design and Implementation* (3rd ed.). Jossey-Bass, San Francisco. 320 pages.

24. National Research Council. 1999. *Being Fluent with Information Technology*. National Academies Press, Washington, D.C. DOI:http://dx.doi.org/10.17226/6482

25. Rikke Toft Nørgård and Rikke Berggreen Paaskesen. 2016. Open-ended education: how open-endedness might foster and promote technological imagination, enterprising and participation in education. *Conjunctions : transdisciplinary journal of cultural participation* 3, 1 (2016), 1–25.

26. Sofia Papavlasopoulou, Michail N. Giannakos, and Letizia Jaccheri. 2017. Empirical studies on the Maker Movement, a promising approach to learning: A literature review. *Entertainment Computing* 18 (jan 2017), 57–78. DOI:http://dx.doi.org/10.1016/j.entcom.2016.09.002

27. Jennifer A. Rode, Mark Stringer, Eleanor F. Toye, Amanda R. Simpson, and Alan F. Blackwell. 2003. Curriculum-focused Design. In *Proceedings of the 2003 Conference on Interaction Design and Children (IDC '03)*. ACM, New York, NY, USA, 119–126. DOI: http://dx.doi.org/10.1145/953536.953553

28. Fredrik Mørk Røkenes and Rune Johan Krumsvik. 2016. Prepared to teach ESL with ICT? A study of digital competence in Norwegian teacher education. *Computers & Education* 97 (jun 2016), 1–20. DOI: http://dx.doi.org/10.1016/j.compedu.2016.02.014

29. Jean J. Ryoo, Lianna Kali, and Bronwyn Bevan. 2016. Equity-Oriented Pedagogical Strategies and Student Learning in After School Making. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 49–57. DOI:http://dx.doi.org/10.1145/3003397.3003404

30. Michael Scaife, Yvonne Rogers, Frances Aldrich, and Matt Davies. 1997. Designing for or Designing with? Informant Design for Interactive Learning Environments. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI '97)*. ACM, New York, NY, USA, 343–350. DOI: http://dx.doi.org/10.1145/258549.258789

31. Heidi Schelhowe. 2013. Digital realities, physical action and deep learning-FabLabs as educational environments. *FabLab: Of Machines, Makers and Inventors* (2013), 93–103.

32. Rachel Charlotte Smith, Ole Sejer Iversen, and Mikkel Hjorth. 2015. Design thinking for digital fabrication in education. *International Journal of Child-Computer Interaction* 5 (sep 2015), 20–28. DOI: http://dx.doi.org/10.1016/j.ijcci.2015.10.002

33. Rachel Charlotte Smith, Ole Sejer Iversen, and Rune Veerasawmy. 2016. Impediments to Digital Fabrication in Education: A Study of Teachers' Role in Digital Fabrication. *International Journal of Digital Literacy and Digital Competence* 7, 1 (jan 2016), 33–49. DOI: http://dx.doi.org/10.4018/IJDLDC.2016010103

34. Elliot Soloway, Mark Guzdial, and Kenneth E. Hay. 1994. Learner-centered design: the challenge for HCI in the 21st century. *interactions* 1, 2 (apr 1994), 36–48. DOI: http://dx.doi.org/10.1145/174809.174813

35. Edna Tan and Angela Calabrese Barton. 2017. Designing for Rightful Presence in STEM-rich Making: Community Ethnography As Pedagogy. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 8, 8 pages. DOI: http://dx.doi.org/10.1145/3141798.3141807

36. Edna Tan, Angela Calabrese Barton, Myunghwan Shin, and Carmen Turner. 2016. Probing Participatory Partnerships: Equitably-consequential Making by, for and with Marginalized Youth. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 1–8. DOI:http://dx.doi.org/10.1145/3003397.3003398

37. The Royal Society. 2012. *Shut down or restart? The way forward for computing in UK schools*. Technical Report. 1–122 pages.

38. Çelebi Uluyol and Sami Şahin. 2016. Elementary school teachers' ICT use in the classroom and their motivators for using ICT. *British Journal of Educational Technology* 47, 1 (2016), 65–75. DOI: http://dx.doi.org/10.1111/bjet.12220

39. Patricia Wastiau, Roger Blamire, Caroline Kearney, Valerie Quittre, Eva Van de Gaer, and Christian Monseur. 2013. The Use of ICT in Education: a survey of schools in Europe. *European Journal of Education* 48, 1 (mar 2013), 11–27. DOI: http://dx.doi.org/10.1111/ejed.12020

40. Jeannette M Wing. 2006. Computational thinking. *Commun. ACM* 49, 3 (mar 2006), 33. DOI: http://dx.doi.org/10.1145/1118178.1118215

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TECHNOLOGY COMPREHENSION – COMBINING COMPUTING, DESIGN, AND SOCIETAL REFLECTION AS A NATIONAL SUBJECT

by

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Technology Comprehension — Combining computing, design, and societal reflection as a national subject

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ABSTRACT

This article considers the implementation of a new learning subject *"Technology Comprehension"* into lower secondary schools in Denmark, as part of an initiative by the Danish Ministry of Education. The subject consists of learning objectives related to computing, design, and societal reflection and was first introduced as an elective course in 13 schools to investigate how it could be integrated into the Danish education system. We present four key findings based on school visits, interviews, an electronical survey, two questionnaires, and workshops including theme discussions: (1) teachers did not perceive Technology Comprehension as a distinct subject, but rather as a set of skills that can be integrated into other subjects; (2) teachers pointed out that Technology Comprehension opens up for interdisciplinary and engaging learning activities, but they need more scaffolding and support; (3) Technology Comprehension challenges teachers' existing competencies and there is a need for a framework that takes into account computing, design, and societal reflection as a whole; (4) Technology Comprehension appealed to various kind of students, not only those who are enthusiastic about technical matters. This study contributes to the previous research on making and digital fabrication by addressing how these endeavours are implemented on a national level through engaging with local teachers. We call for more research on scaffolding and supporting teachers to orchestrate meaningful learning activities to successfully integrate Technology Comprehension into the Danish national education.

1. Introduction

This paper considers the implementation of a new subject – *Technology Comprehension* – across lower secondary schools in Denmark. Technology Comprehension (TC) is a translation from the Danish word *"Teknologiforståelse"* and consists of learning objectives related to computing, design, and societal reflection. A shorter version of the paper was presented in the Fablearn Europe conference and this version expands the original paper by carrying out a more in-depth literature review and by presenting additional results in Section 5.3 [1].

TC was initiated by the Danish Ministry of Education and it is currently offered as an elective course to Danish lower secondary education schools (13–15 y.o. students). TC is composed of the three major learning objectives to develop (1) basic skills in computing, such as programming, algorithms, pattern recognition, and abstraction; (2) skills to specify and articulate a problem and utilise an iterative design process to develop a digital solution; and (3) skills to reflect and evaluate the digital solution, its applicability, impact, and ethical concerns with reference to the broader socio-political context within which it is applied.

The research project was initiated in October 2017 in a collaboration between the Centre for Computational Thinking and Design at the Aarhus University and the Danish Ministry of Education (Fig. 1). The research objective was to examine the response to the implementation of TC, and support its implementation across 13 Danish lower secondary education schools. In particular, we focused on three questions: (1) how teachers perceived their competency in teaching TC; (2) what opportunities and challenges teachers experienced when teaching TC; and (3) what type of students participated in TC. The research questions were investigated through school visits, interviews, an electronical survey, two questionnaires, and workshops including theme discussions.

Digital literacy is essential for preparing children for the opportunities and challenges of a fast-moving, globalised, and increasingly digitalising world [2]. Several initiatives have been established to support the development of students' digital literacy, including CS4all,[1] Code.org,[2] and Computer Science Teacher

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1 CS4All, www.cs4all.io, retrieved 14.3.2018.
2 Code.org, code.org, retrieved 14.3.2018.

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- Trial period from 2017 to 2020
- 13 public schools in Denmark, selected by the Ministry of Education to represent different geographical areas and socio-economic diversities
- 20 teachers and 303 students in the first year of the project
- In 2019, 45 schools will have TC as a compulsory program
- In 2021, TC will be compulsory for K-9 students

Fig. 1. Specifications of implementing TC in Denmark.

Association[3] These initiatives are inspired by *computational thinking*, which was first popularised by Wing [3], and later defined by Aho [4] as: "*thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms*". For example, computational thinking has been just recently integrated into the national curriculum in the United Kingdom [5].

Through TC, we introduce an alternative approach to development of these skills by (1) integrating computing and design skills into the learning process as means, rather than viewing these skills as mere learning outcomes; (2) supporting creativity through the development of technology to understand the impacts of technology; and (3) to critically reflect the role of technology in the society more broadly. Thus, TC is grounded in the values commonly associated with Scandinavian participatory design [6], such as democracy and empowerment, and draws from previous research on the integration of design competences in educational contexts [e.g. 7,8]. Furthermore, TC builds on the previous Danish initiatives designed to promote digital literacy development, such as Fablab at School [7], Coding Class [9], and Coding Pirates [10]. TC is strongly connected to *making* and *digital fabrication*, as it involves computing activities, collaboration, prototyping, and iterative design to create digital artefacts and aims to promote self-cultivation and democratisation [8,11–14].

The paper is structured as follows: Section 2 provides background on four topics of TC from within a Nordic educational context. Section 3 describes TC more in detail, including goals and learning objectives that were defined by the Danish Ministry of Education. Section 4 explains how the study was carried out, including research questions, data collection procedures, and analysis methods. Finally, Section 5 presents the results, Section 6 discusses four themes that were derived from the results, and Section 7 concludes the paper and addresses study limitations and future research.

2. Background

The three core components of TC – computing, design, and societal reflection – have relevance to several research disciplines, including Educational Research, Human–Computer Interaction, and Computer Science. Computing and computational thinking are a particular focus in the fields of Computer Science Education and Computing Education Research [e.g. 15,16]. Approaches to designing with children, also in educational context, is a focus of the Interaction Design and Children community [e.g. 17–21]. Furthermore, societal reflection is related to research on empowerment and democracy in technology design [e.g. 22,23]. As the theme of this special issue is making and digital fabrication, this literature review focuses on these two topics.

Section 2.1 introduces making and digital fabrication in the formal education. In Section 2.2, we build context for TC by examining national curricula of three other Nordic countries. Section 2.3 focuses on the teachers' skills and competence because teachers were the main stakeholders in the study. Finally, in order to consider the impact of TC, Section 2.4 reviews previous literature about student engagement.

2.1. Making and digital fabrication in formal education

Making and digital fabrication have gained a lot of attention in recent years [see 13,24–26]. This endeavour was driven by a shift in focus away from mere skills to use technology towards digital literacy, need for creative and design skills in engineering, and the increased availability of prototyping equipment [13,14]. The idea is grounded in Dewey's democratisation, Papert's constructionism, and Freire's critical pedagogy, which are actualised when connecting democratisation and empowerment with learning-by-doing approaches [13]. These activities are carried out at *makerspaces* or *fablabs*, where children aim to create meaningful and shareable artefacts [26].

Several scholars describe the benefits of making and digital fabrication for learning. Katterfeldt et al. [24] argue that it provides opportunities to interact with concrete objects-to-think-with, to link personal interests and learning activities, and to develop self-efficacy. Blikstein [13] states that it provides an environment for working in the design process with an interdisciplinary approach. Martin [26] proposes that it provides sophisticated tools to build and think, and a tolerant environment for experimenting, playing, and making errors. Chu et al. [27] found that through making children acquired technical skills, mental models about troubleshooting and problem decomposition, as well as means to share ideas and responsibilities. However, it has been criticised that these benefits are over-romanticised and do not necessarily actualise in the formal classroom context [e.g. 28].

Research on making and digital fabrication has recently been expanded into formal education contexts [e.g. 26,27,29–31]. According to these studies, there are several areas that require greater attention. Berman et al. [29] question how making could evolve beyond individual sessions to established, sustainable practices in the classroom, Martin [26] questions how making can align with the goals and needs of schools, whilst Eriksson et al. [31] call for an examination of the relationship between pedagogical practices and making activities. Furthermore, there is also need for research to explore applications of making in non-engineering contexts (e.g. social sciences and arts), because studies of making and digital fabrication occur predominantly in the context of STEM, Computer Science, or Natural Sciences [e.g. 11, 30,32,33].

The most seminal work related to implementation of TC was conducted by Eriksson et al. [31]. They investigated a national distributed Makerspace project and derived five main considerations for initiating and running a large-scale national project: (1) procurement practices, such as identifying appropriate tools and materials for schools, partnering up with companies to develop educational materials, and standardising maker kits for education; (2) professional training and knowledge sharing with mutual understanding between teachers and school leaders; (3) the need for informing national policy-making to support general management, for example, of joint teaching material and curriculum development; (4) creating equal opportunities for both genders, especially for girls; and (5) creating initial interest with simple activities and progressing towards more challenging and advanced projects.

3 Computer Science Teacher Association, www.csteachers.org, retrieved 14.3. 2018.

2.2. National curricula in the Nordic countries

As the context of this study is the Danish national education, we consider the national curricula on three neighbouring Nordic countries of Denmark: Sweden, Norway, and Finland. Note that the curricula in these countries do not use making and digital fabrication specific concepts, but discuss digitalisation, digital technology, and information and communication technology in more general level.

The Swedish K-12 curriculum [34] was recently (2017, in action since June 2018) changed towards a stronger emphasis on utilisation of digital technology, opportunities and risks of digitalisation, and how digitalisation is affecting the development of society. In Norway, the curriculum addresses educational goals in a high abstraction level [35]. Technology, in the sense of its development and importance, is discussed in relation to a working human-being, ecological sustainability, and societal impact. In Finland, the new curriculum positions information and communication technology (ICT) as one of the seven embedded transversal competencies [36]. For the ICT competence, students should reflect how technology is related to sustainable development, to everyday communication and interaction, and even to political influence. As seen, these curricula have a holistic approach regarding the use of technology in education. Technology-related skills and knowledge are conceived as fundamental for well-being and self-realisation, instead of mere future working life capabilities.

When it comes to computing skills, Finland and Sweden differ from Norway. In Sweden, algorithmic thinking and programming are introduced in mathematics in the primary school — basics of programming for the grades 1–3, and introduction of algorithms and visual programming environments for the grades 4–6. In Finland, the embedded transversal competence of ICT is defined for grades 1–2, 3–6, and 7–9. Accordingly, students get acquainted with programming as early as in the first year of school and develop their computing skills from an abstract level towards writing programming languages. In turn, the Norwegian curriculum currently lacks the computing specific perspective, but there is an ongoing effort of examining how it is incorporated into education [37].

Swedish K-12 curriculum stands out from the two others with design-related skills, such as identifying problems and utilising a design process to develop alternative solutions. In contrast, Finnish and Norwegian curricula concentrate on the perspective of using technology for learning purposes, such as searching, processing, producing, communicating, and judging information in a digital form.

As a conclusion, the three Nordic countries share the view that learning technology should be firmly embedded within a broader socio-political context. Sweden and Finland specify that it includes at least the basics in computing, such as programming, whereas only Sweden outlines that technology education should provide opportunities to create new solutions and artefacts.

2.3. Teachers' digital competence

The Fablearn Fellows Program is an important channel for disseminating making and digital fabrication to schools. It provides open source curricular materials, guidelines, and support for schools [38]. Utilising these resources, however, still relies on individual teachers. The large survey among the teachers who belong to the Computing At School (CAS) network in the UK shows that after significant curriculum change, teachers encounter a diversity of challenges, including teachers' limited technological skills and knowledge, technical problems, didactic differentiation, a limited ability of students to understand the content, and lack of students' general willingness or ability to solve problems [16].

Teachers' technological skills and knowledge have been considered through the concept of digital competence. Based on a large meta-analysis, Ilomäki et al. [39] defined that teachers' digital competence consists of the technical competence, the ability to use digital technologies in a meaningful way, the ability to evaluate digital technologies critically, and the motivation to participate in the digital culture. Røkenes and Krumsvik also applied meta-analysis and defined four teachers' competence levels: basic digital skills, didactic competence, learning strategies, and *digital Bildung* [40,41]. While both of the digital competence frameworks take into account the societal impact of technology and its development, neither of them includes computing-specific skills, such as programming, or design-specific skills.

To orchestrate making and digital fabrication learning activities, teachers need knowledge in technical matters as well as the ability to foster learning through design. According to Smith et al. [8], teachers need to (1) foster students' reflection and knowledge construction, instead of focusing on functionality or aesthetics; (2) to view technology as flexible processes and materials instead of fixed products; and (3) to pivot between the roles of classroom teacher, design facilitator, and coach. Teacher support can be provided in the form of real-world examples, emphasis on problem-solving and hands-on experience, scaffolding, peer mentoring, and collaboration [16,42]. Teachers may also benefit from access to makerspaces, separated from students, where they could explore and learn without having to fear losing control or authority in front of their students [43].

2.4. Student engagement categories

The importance of *engagement* to counterbalance low levels of academic motivation and achievement is well understood in the literature [44]. Engagement can be divided to behavioural, emotional, and cognitive engagement, and thus, its application in research should be accompanied with a clear definition. [45]. For example, the contradictory role of student engagement in a fablab context was depicted by Blikstein [13, Section 4.1]. Finn and Zimmer [46] found that engagement can be facilitated through didactic arrangements that foster cooperative student–student interaction, in-depth inquiry and meta-cognitive actions, and authentic instruction to construct meaning beyond the classroom can facilitate student engagement. The engagement behaviours and profiles in the learning environment are responsive to teachers' and schools' practices [46].

In relation to student outreach, one can investigate how getting acquainted with Computer Science through making events, such as coding clubs and game programming workshops, raise interest and engagement in the subject [e.g. 47]. Based on the four-phase model of interest development as defined by Hidi and Renninger [48], Lakanen and Kärkkäinen [49] identified four K12-student categories and pathways characterising the longer-term impact of the computing activities. However, in this work, we focus on a short-term assessment of TC. In order to depict different types of engagement in learning through design, we utilise the framework that was recently developed in the context of FabLab schools in Denmark. There, Smith and Iversen [6] defined five archetypical student categories based on interviews and surveys with the students.

In the *design competent* category, students demonstrate the development of language, repertoire, and design literacies through problem-solving. The student profile in this category closely resembles Category I—"Confirmed career option" —in [49]. The *tech-savvy* students in the second category are engaged with technical challenges that, for example, programming provides (cf. [47], Category II: "Novel career option" in [49]). The *well-schooled* category represents students who have no troubles in meeting the learning objectives, but who do not show interest in technology-related topics (cf. Category III in [49]: "Stick to other plan"). The *undecided* students are not convinced by the relevance of technology or design, other than part of school work, whereas the *not (yet) motivated* students feel that technology-related activities have little sense for them (cf. Category IV in [49]: "Confirmed not interested"). We apply these archetypical categories to consider what kind of students TC elective courses can reach, serving as a pre-step for investigating the impact of TC on students' perceptions in the future.

3. Technology comprehension

We now draw the attention on the current initiative in Denmark, where the Danish Ministry of Education defined TC as a new subject for the lower secondary education. The curriculum was formulated by three experts in education. TC was first piloted in 13 schools as an elective course during fall 2017. The teachers, who were assigned to teach TC, had not received supplementary or in-service training to teach the subject. During 2018–2021, TC will be experimented in over 40 schools to investigate the three implementation options: An independent subject running from first to ninth grade; an integrated subject to existing subjects; or combination of both, where TC is integrated into other subjects from first to sixth grades and then thought as an independent subject from third to ninth grades.

The Danish Ministry of Education [50] has defined that TC needs to consider: (1) The implications of technology and automation on society, including an understanding of security, ethics, and consequences of digital technologies; (2) Computing as a knowledge area, including basic knowledge of networks, algorithms, programming, logic and algorithmic thinking, abstraction and pattern recognition, as well as data modelling and testing. (3) Iterative design process as an interaction between gaining an understanding of the world that is being designed to and gaining an understanding of the digital technologies that are being designed with. (4) Complex problem solving, where children create new digital solutions and, hence, learn to argue for their relevance through an understanding of design processes.

Consequently, TC includes [51] three major learning objectives: (1) Students learn how to produce and analyse digital products. (2) Students learn to develop, modify, evaluate, and refine digital products through work with remixing, refinement, and production. (3) Students learn the possibilities and role of informatics as a catalyst for changes in the society, in order to strengthen the capabilities for acting in a meaningful way in a democratic and digital society, including constructive and critical contribution in shaping the digital society.

TC has some intersections with computational thinking and especially with computational concepts, practices, and perspectives [as defined in 3,52,53]. However, TC differs significantly from computational thinking in the following areas: Firstly, it treats computing and design as equal competency areas. Secondly, these two areas are dependent on each other, in order to develop students' capabilities to analyse, design, and develop digital products. And thirdly, it integrates the societal reflection, meaning the critical reflection of the societal impact of technology, as a part of the learning objectives. In this sense, TC is related to [12]'s *"Bildung"*, as a way of considering complex and sustainable learning. These three standpoints are all related to, but different from similar initiatives, such as CS4all in the United States, CoolThink in Hongkong, and Computing in the United Kingdom.

4. Methods

An overview of the research process is shown in Table 1. After the project was initiated, we started the research by sending an electronic survey to the participating schools. The survey asked about the teacher's professional background, anticipated challenges regarding TC, and expectations of being part of the project. During winter 2017, we visited the schools and carried out semi-structured interviews with 14 teachers [54]. The interviews explored the teachers' expectations (if not yet teached TC) and experiences (if already teached TC) regarding TC. For the teachers who had already teached TC, we handed the *"five archetypical student categories"* [6], described in Section 2.4. We presented these categories to the teachers, discussed what the categories stand for, and asked them to assign their students within these categories. We also observed TC teaching activities during the school visits, if it was possible. Based on these preliminary investigations, we clarified the research questions as:

RQ1: How the teachers perceived their competence to teach TC?

RQ2: What opportunities and challenges the teachers perceived when introducing TC?

RQ3: What form of student engagement the teachers recognised in TC classes?

Because one goal of the project was to support the teachers, we decided to arrange a one day workshop. The workshop had three-fold purpose: to provide support and training for the teachers; to involve the teachers to discuss possibilities and challenges of TC; and to gather data for this study. Before the workshop started, we informed all teachers about our data collection purposes and provided them with a self-assessment questionnaire. The workshop program consisted of familiarising with each others, examining the TC learning goals, and practical hands-on tasks with Micro:bits. After the workshop, the teachers answered to a feedback questionnaire (e.g. what did they learn in the workshop).

During the workshop, we also arranged a theme discussion about TC. The topics of the theme discussion were: What is TC as an elective course for you, how do you incorporate TC in your current teaching, how do you perceive the competency goals, and what should TC be in future? For the theme discussion, we supplied the teachers with a handout of TC learning objectives. The discussion was moderated by one of the researchers and recorded with two video-cameras.

The workshop was executed two times in different regions of Denmark, once in Aarhus and once in Copenhagen (see Table 2). In Aarhus, there were nine participants from seven schools (eight teachers and one pedagogical consultant). In Copenhagen, there was also nine participants (seven teachers and two school principals).

For the RQ1, the self-assessment questionnaire consisted of four Likert scale question sets [55]. The first set was accustomed from the digital competence framework [41], which examines teachers' general competences regarding digital tools: using digital tools in spare time (e.g. online banking), using digital tools in work (e.g. office tools and presentation), using digital tools in instruction (e.g. learning resources in web), guiding students to improve their learning strategies with digital tools (e.g. reading screen-based text, note-making, mind-maps), and guiding students in ethical matters related to digital tools (e.g. plagiarism, social media). Because this question set does not consider programming, we added three questions about programming competence: visual programming language (e.g. Scratch), programming (e.g. Javascript), and debugging. The two other sets examined

Table 1
Technology comprehension research process.

Date	Participants	Activity	Data
October 2017	Representatives from the Aarhus university and the Danish Ministry of Education	Project initiation	Official documents (e.g. learning objectives and official documentation of TC)
October 2017	14 teachers from 13 schools	Electronic survey for schools	Survey answers
November 2017–January 2018	14 teachers from 13 schools and researchers	School visits	14 recorded interviews, field notes, student categories form
19th February 2018	8 teachers, 1 pedagogical consultant, and 3 researchers	Workshop in Aarhus (including theme discussion)	Workshop recording, self-assessment questionnaire, and feedback questionnaire
21 February 2018	7 teachers, 2 principals, 3 researchers	Workshop in Copenhagen (including theme discussion)	Same as in Aarhus

Table 2
Teachers' teaching background ($n = 18$).

#	Subjects	Teaching experience (years)
Workshop in Aarhus		
1	IT pedagogy	Over 10
2	Math, physics, chemistry, history	3–5
3	History, societal, physics, chemistry, IT	Over 10
4	Math, physics, chemistry, TC	Over 10
5	Languages, math, sports, household, nature and technology	3–5
6	Math, sports, IT/Fablab	Over 10
7	Math, nature and technology, religion, crafts and design, TC	Over 10
8	Danish, music, fablab	Over 10
9	Math, nature and technology, science	Over 10
Workshop in Copenhagen		
10	English, history, crafts and design	5–10
11	Nature and technology, TC	0–2
12	Music, English, TC	0–2
13	Danish, religion, sports, music, TC	0–2
14	History, religion, nature and technology, biology	0–2
15	Math, physics, chemistry, TC	5–10
16–18	Unknown	Unknown

Table 3
Perceived competencies of the teachers ($n = 15$).

		1	2	3	4	$\sum$	Mean	SD
Digital competence	f	0	7	26	42	75	3.47	.48
5 questions	f/n (%)	0.0	9.3	34.7	56.0	100		
Programming competence	f	18	13	9	2	42	1.93	.64
3 questions	f/n (%)	40.0	28.9	20.0	4.4	93.3		
Teaching design concepts	f	3	11	27	1	42	2.62	.60
3 questions	f/n (%)	6.7	24.4	60.0	2.2	93.3		
Teaching computing concepts	f	27	30	28	2	87	1.76	.68
6 questions	f/n (%)	30.0	33.3	31.1	2.2	96.6		

Scale: 1 = not competent, 2 = little competent, 3 = competent, 4 = highly competent.

the teachers' perceived capability to teach design and computing related concepts. The design concepts were idea generation, fabrication, and societal significance and the computing concepts were patterns, algorithms, data structures, coding, programming languages, and testing.

Answers to the Likert scale questions were analysed with IBM SPSS Statistics. All *"I don't know"* answers were treated as missing answers, and excluded from the analysis. The first analysis involved the calculation of frequencies, frequency distributions, and portions. The four question sets were transformed into four Likert scale constructs to calculate the means and standard deviations. However, the internal consistency of the constructs could not be verified due to the small sample size. We also compared the two workshops using the Mann–Whitney test and found no statistically significant differences between the workshops.

For the RQ2, we first translated and transcribed the theme discussion in English, because all authors are not fluent in Danish. Then, we carried out a collaborative content analysis of the theme discussion [55]: we negotiated the high-level objective of the analysis, watched the discussion recording, and made notes individually. Then we discussed different interpretations and constructed themes based on the research question. We triangulated the findings by analysing the answers to the electronic survey, self-assessment questionnaire, and feedback questionnaire.

For the RQ3, we analysed the student category forms, which were filled during the school visits and, in some cases, provided to us after the workshop. It needs to be noted that the student frequencies in these categories do not represent the students as such, but rather the teachers perceptions how they would define the students who took part in TC. Moreover, the teachers stated that determining the category that represented each student was challenging and should be considered as only a rough estimate.

5. Results

Here we present the findings to the three research questions.

5.1. RQ1: Teachers' perceived competency

Fifteen teachers answered to the self-assessment questionnaire. As can be seen in Table 2, seven teachers had more than ten years, four teachers had three to ten years, and four teachers had less than two years of teaching experience. The teachers had taught the following subjects: TC, math, physics, chemistry, history, crafts and design, social studies, IT, Danish, sports, Fablab, nature and technology, religion, German, music, biology, and food Literacy.

The teachers perceived their competence to use digital tools in education high (Table 3). Altogether 90.7% of the answers to the five questions were either competent or highly competent. In the programming competence questions, almost all (14) teachers answered that they had at least some competence with visual programming languages, such as Scratch. On the other hand, most of the teachers (10) had no competence in programming with a text-based language. This reveals that while the teachers considered themselves as digitally competent, most had only expertise in using visual programming languages. We also asked how the teachers perceive their competence to teach TC concepts. Over 60% of the answers to teaching the design concepts were competent or highly competent. In contrast, only 31.1% were competent or highly competent regarding computing concepts.

Besides the presented competencies, it is worth noting that two of the teachers had been part of the expert group in the Danish Ministry of Education. The group had formulated the exact competency areas, competency goals, proficiency goals, and knowledge goals for TC. As a conclusion, the teachers perceived high digital competence and most of the teachers had a lot of teaching experience and from a broad range of subjects. The teachers considered themselves more competent in teaching design concepts than computing concepts.

5.2. RQ2: Opportunities and challenges of TC as a subject

Two of the Danish Government's implementation options position TC as an individual subject. Despite this, the teachers addressed TC as a component of some other subjects. For example, a teacher considered TC as mere programming skills: *"We created programming and maths course that starts in the first grade and runs through all grades. Programming is okay, but should not be a standalone subject, it should be part of the other subjects. A tool"*. Likewise, the teachers considered TC as a tool for learning other subjects: *"I think a lot about how it can be part of natural science subjects. Currently, I am also teaching crafts, where I think that it could fit in. But, as I said, I also think that having it as a part of natural science would be very exciting for me"*. This also became apparent when the teachers talked about the tasks that they involve the students in, as noted by a teacher: *"they [students] created math games"*. Another teacher had integrated other subjects, such as entrepreneurship, into TC: *"I tend to focus on the Design part of the subject because that is what I find awesome, this entrepreneurship and I try to keep asking the students questions if they claim that they are done 'Design a Logo', 'Find a company name', 'Create a business model'"*. As a conclusion, these perceptions indicate that the teachers lacked formalised ways of addressing TC as a distinct subject, as explicitly coined by one of the teachers: *"This new thing that is starting, I think about it as part of the existing subjects"*.

As indicated by the previous examples, when considering TC, the teachers displayed mainly episodic knowledge: the teachers' arguments derived from their own, or others, practices of using technology in education. Despite the fact that the learning goals of TC were provided to the teachers, the arguments for the subject reflected their personal beliefs, experiences, and interests. For example, the teachers with design background emphasised design goals, teachers with computing background computing goals, and teachers with humanistic background societal goals. Thus, the teachers did not have a mutual understanding of what TC was, or what it should be in the future, but instead relied on personal preferences and episodic knowledge.

Most of the discussed opportunities were confused with technology-supported education. The teachers referred to examples how technology can support students: *"I can have students that are creating a paper booklet, and right next to them another group that works with creating a blog. Both make equal sense. Then you do have students that are able to concentrate for more than 25 min because you have access to different technologies"*. Another example was using technology to engage students with special needs: *"I had an experience, where mother of a dyslexic child contacted me. Usually, when the girl had to make presentations, she was embarrassed by doing it. She used the computer to make the presentation and felt more capable of presenting due to the auto-correction tools"*. In addition, the teachers brought up the opportunity to motivate students, who use digital tools in spare time or to concretise abstract topics, such as perceiving the coordinate system using Scratch.

The teachers presented several narratives how TC engages different students. For example, a teacher said: *"We have had some boys that were very hard to engage in other subjects, that have been very engaged and therefore also very cooperative on this matter"*. This was followed up by an example in special education context: *"I have never gotten them to focus for more than 25 min, now they have been working for 90 min"*. In general, the teachers agreed on the fact that TC is an engaging subject, as concluded by a teacher: *"[TC] is fun, and a lot of students get engaged by it"*.

A recurring theme was that TC opens up for more student-centred learning. A teacher elaborated on the 9th graders' sense of ownership towards making math games to 1st graders: *"We were making math games with Scratch, it was obvious that older students had a sense of ownership to this assignment. The 9th graders were supposed to make a math game for 1st graders. The day before, 9th graders used their lunch break to go to 1st graders and check if the level was too hard. Then 9th graders went back and adjusted the games. That's very uncommon to 9th graders to do something like that in own time"*. This was also exemplified by another teacher, highlighting how TC integrates topics that are relevant to students: *"My focus is to have a starting point that the students can relate to, for example, in the Odense municipality we are establishing the new light-rail. The students were concerned about what if a blind person should cross the light-rail, can we be sure that the train will stop. So they tried to build some censors with Micro:bits. This was the classical problem-solving setting that the students could relate to"*. These examples demonstrate the opportunity to actualise TC as a design process that integrates computing, the societal reflection, and problem-solving.

As illustrated by the previous quotes, the teachers appreciated the fact that TC combines computing, design, and societal reflection together. They pointed out that, normally, computing-related curricula are designed by people with the computing background. Hence, the learning objectives tend to address mere computing goals. TC opens up for holistic subject goals when it is designed by stakeholders from the various subjects.

Several challenges emerged from the data. The teachers' conceptions indicated uncertainty about the meaning of the societal reflection in TC. The teachers discussed the societal reflection primarily as a means to contextualise the subject with real-world problems. They referred to topics that were familiar from previous teaching experiences in other subjects, such as *"fake news"* in social media, election meddling, and the earlier example about the light-rail track in Odense. Thus, the teachers considered the societal reflection of TC as a means to contextualise classroom activities, instead of a learning objective as such.

The teachers described the varying digital skills of students as a major challenge to teaching. A teacher told that: *"I have some boys in my elective course and even before I started the teaching they had downloaded the files we should use. At the same time, I had a girl who did not know what a file is. The students had very different skills for participating in this field"*. Another teacher noted that if TC is first introduced in the seventh grade, the prerequisites of the subject are necessarily low. Otherwise, lack of basic skills, such as basic computer use, will prevent those students to pursue the actual learning goals: *"I would like to be better at presenting the students with a problem as a starting point, where they can analyse, design and develop. Currently, they have mostly worked with learning the different technologies"*.. One teacher concluded that if the basic computing skills are to be taught in TC, it leaves less space and time for other learning objectives.

Another challenge was that students have different needs regarding the structure and guidance of TC learning activities. Some students want to be challenged and to be provided with less guidance, while others are incapable of acting without clear structure and instructions: *"Some of them expect to be challenged, some of them expect to get everything served on a silver plate. That is one of the biggest challenges I have to get them to be better"*. This indicates that TC, as a new subject, calls for a high level of individual differentiation of the learning activities.

Finally, we identified further challenges related to the gender disparities and teachers' need for time and peer support. As demonstrated by the earlier quotes, there is a gender disparity around students skills and interest in TC. For example, a teacher stated: *"A lot of students want to participate in 4–6th grade, in 7–9th grade, it is primarily boys"*. The teachers' conceptions distinct between boys, as being interested and knowledgeable, and girls as not necessarily interested, or engaged, in TC. The teachers pointed out that teachers need more time, peer support, and scaffolded teaching instructions to be able to implement TC as a new subject. As concluded by one teacher: *''[TC] is a new subject and a new way of thinking in primary school. It requires more preparation time than the 'normal subjects', where you can adopt a lot of existing teaching material from various learning portals into your own work''.*

5.3. RQ3: Student engagement in TC

Teachers from 11 out of 13 participating schools reported back on their perception of students' characteristics based on five archetypical student categories [8]. Two schools chose not to participate in this part of the interview or were unable to account for the student profiles. The number of students from each of the five archetypical categories is accounted in Table 4 in relation to the total number of students on each school.

Generally, each course had a very limited number (1–3 students pr. class) of *design competent* students. This is consistent with our hypothesis as technology comprehension is a new subject matter. Hence, students do not have any prior formal training in technology comprehension. However, there are three schools with significantly more students in this category; 6 design competent students at schools 7 and 9, which could relate to the teacher's lack of knowledge of the students (one teacher had only known the students for a few weeks at the time of the interviews) and 15 design competent students at school 10 relating to the teachers own interpretation of TC as a subject (the teacher stressed that entrepreneurship and innovation was a part of the curriculum which it is not formally. The number of *tech-savvy* students was also very limited in the TC courses. Only 2–3 students per class were characterised by these competencies. The relatively low number of tech-savvy students came as surprise to the researchers. We expected to find a large number of tech-savvy students, who would sign up for the elective course, as this would allow them to work with digital technology inside the formal education).

The number of *well-schooled* students diverges significantly from school to school. Schools 3 and 6 reported that none of their students in the TC course can be considered as well-schooled, whereas school 4 categorised 10 (out of 31) and school 10 categorised 10 (out of 25) as well-schooled students. The *undecided* students were generally well-presented in the TC course. In some schools (1,4,5,11), teachers had done extra effort to recruit students from this category to the TC course. The teacher from school 5 emphasised that the reason for the large proportion of undecided students in the class (30 students) is directly linked to his own inability to explain to the students why TC is important, which inevitably makes the overall purpose with the subject unclear and difficult to engage in. In some of the schools, almost half of the course participants can be categorised as undecided. Finally, Table 3 accounts for the number of *not-yet-motivated*. Aside from schools 5 and 6, all TC courses engaged a number of not-yet-motivated students. In the school 4, 30 out of 40 students represented this category. The teacher from that school reported that the course description was designed to accommodate the interest of this particular category of students, which explains the high number of students from this category. Exactly the same phenomenon has been visible in the student outreach — related profiles (see [49] and Section 2.4). Overall, it must be considered that TC is an elective subject, and some students did not pick it as their first priority, but as a second or even third priority.

6. Discussion

Our findings derive from the first year of implementing TC as a national subject. Despite the fact that we are early in the process, the teachers provided us with important practice-based knowledge about TC and its further development. To discuss our findings, we have developed four themes: (1) teachers did not perceive TC as a distinct subject; (2) TC opened up for interdisciplinary and engaging learning activities; (3) TC challenged teachers' existing competencies; and (4) TC appealed to various kinds of students.

Teachers did not perceive TC as a distinct subject. Our research is associated with current efforts of incorporating computing and design in formal education [7,27,31,42,53]. Our main finding was that teachers did not see TC as a distinct subject, but rather as a set of skills that can be integrated into other subjects. This may be due to the fact that TC is a subject coined by the Danish Ministry of Education and, thus, not well-known among teachers or in research. This relates to what Smith and Iversen [8] considered as the impediments of digital fabrication in education. Whereas they pointed out that teachers generally lack a sufficient understanding of design processes and complex problem solving, our study showed that teachers did not perceive computing, design, and societal reflection together as a distinct subject. Eriksson et al. [31] points to the need for informing national policy-making to support general management of joint digital fabrication teaching materials and curriculum development. Similarly, developing TC as a subject should not be left only to the teachers' responsibility, but rather, to the responsibility of the entire TC initiative and ultimately to research.

TC opened up for interdisciplinary and engaging learning activities. We found that teachers identified several opportunities in TC: it encourages children to be creative with digital technology, to work with authentic and complex problems and to take responsibility for their learning process [cf. 24]. Moreover, the teachers thought that students perceive TC learning activities as engaging, inspiring, and fun [cf. 27]. TC shares [12]'s reasons for introducing digital fabrication in curriculum-based education: developing computing skills together with cultivating a digital citizenship. Hence, TC promotes digital competencies as critical and reflective personal skills that relate to *Bildung* [12, 40], computational empowerment [22], democracy and empowerment [13], and also to the computational perspectives in [52]. While the teachers discussed how addressing digital technology from a critical and societal point of view is an opportunity, they did not feel capable of bridging between hands-on activities and more abstract discussion of computational perspectives. To fulfil the opportunities of TC, there is a need for scaffolding activities, such as in-service training, development of learning materials, and online resources [31,43,56].

TC challenged teachers' existing competencies in relation to the subject and students' prerequisites and needs. We identified the following challenges: the lack of shared understanding about the meaning of the societal reflection in TC, students' varying skills and needs, and the paradox between instructional structure and freedom, and the lack of girls' involvement. Some of the challenges are already known in research, for example, balancing between creative digital fabrication activities and formal educational structure [8,31,42,56] and the gender imbalance [31]. We argue that a crucial challenge is the lack of teachers' competency framework that considers computing, design, and societal reflection as a whole. Current national and international frameworks understand digital competence as a capacity to use technology for other learning purposes. For example, Norwegian framework includes mere digital skills, consisting of searching and processing information from digital resources [57] and European Framework

Table 4
Teachers' perceptions of the student engagement categories in TC course.

School	Design competent	Tech-savvy	Well-schooled	Undecided	Not (yet) motivated	Total
School 1	1	3	3	12	6	25
School 2	3	2	4	4	1	14
School 3	2	3	0	5	5	15
School 4	0	1	10	10	10	31
School 5	3	1	6	30	0	40
School 6	3	3	0	4	0	10
School 7	6	2	3	5	6	22
School 8	1	2	4	6	5	18
School 9	6	2	7	2	3	20
School 10	15	3	5	5	2	30
School 11	1	2	10	10	2	25
Total	41	24	52	93	40	250
Total %	16.4	9.6	20.8	37.2	16.0	100.0

for the Digital Competence of Educators consider teachers' use of digital tools only for communication, collaboration, and professional development [58]. Hence, we call for defining subject knowledge for teachers to educate digital technologies through learning activities that utilise design process, entail computing skills, and aim for personal empowerment.

TC appealed to various types of students. With reference to the archetypical categories [6], we found that TC appealed to various types of students in Denmark. This was due to two factors: First, many schools in the Danish project made a deliberate choice to target *undecided* or *not-yet motivated* students, not only the tech-savvy, in their TC elective course. The teachers accounted for this choice by arguing that digital technology is first and foremost a democratic matter. Accordingly, schools must provide every student with an opportunity to prosper and actively engage in a digitalised society. Second, the schools adjusted content from computer science, digital fabrication, digital design, and humanities to customise a curriculum that would attract students with less prior knowledge or interest in programming and algorithms. As such, this implementation strategy of TC resonates well with the general Nordic approach, which has a strong emphasis on understanding the opportunities and risks of digitalisation from the societal reflection [34–37].

7. Conclusion

Educational researchers have warned that implementing educational reforms with purely top-down approach can lead to failure [59]. This study contributes to the previous research on making and digital fabrication by exploring how these endeavours can be implemented on a national level by engaging with teachers on a local level. Based on interviews, surveys, questionnaires, and the theme discussion with highly experienced teachers, we found both possibilities and challenges in implementing the new subject: Teachers did not yet perceive TC as a distinct and legitimate subject, TC opened up for interdisciplinary and engaging learning activities, TC challenged teachers' existing competencies in relation to the subject and students' prerequisites and needs, and TC appealed to various types of students. Taking these findings into account helps the Danish stakeholders to better understand the impacts of educational reforms from teachers' perspectives. Hopefully, these findings can be also applied in other contexts, by informing what kind of issues may emerge in this kind of initiatives.

We identify the following shortcomings in our study: Our findings derive solely from collaboration with teachers, which leaves out crucial stakeholders, such as policy-makers, parents, and students. We have not taken into consideration that many teachers will ultimately teach TC without prior experiences or any compulsory education in TC, which may exacerbate the need to better support teachers. Finally, as already stated, our study focused on literature in making and digital fabrication, and future research should take into account other fields as well, such as Computing Education Research and Learning Sciences.

The challenges of implementing the political agenda to offer TC for all students in Denmark should be addressed merely as a general lack of research about TC. Thus, our study raises several questions: How do we draw from previous research on computing and design education to consider computing, design, and societal reflection as a combined subject? How do we develop supplementary training for pre-service and in-service teachers to support their TC teaching practices? How do we develop assessment strategies that take into account the development of computing and design skills with the capability of critically reflect technology as a whole?

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Conflict of interest

The authors declare that there is no conflict of interest in this paper.

References

[1] A. Tuhkala, M.-L. Wagner, N. Nielsen, O.S. Iversen, T. Kärkkäinen, Technology comprehension - scaling making into a national discipline, in: Proceedings of the Conference on Creativity and Making in Education - FabLearn Europe'18, no. June, ACM Press, New York, New York, USA, 2018, pp. 72–80, http://dx.doi.org/10.1145/3213818.3213828.
[2] European Commission, Communication on the Digital Education Action Plan, Tech. Rep., European Comission, Brussels, 2018, p. 11.
[3] J.M. Wing, Computational thinking, Commun. ACM 49 (3) (2006) 33, http://dx.doi.org/10.1145/1118178.1118215.
[4] A.V. Aho, Ubiquity symposium: computation and computational thinking, Ubiquity 2011 (January) (2011) 1, http://dx.doi.org/10.1145/1922681.1922682.
[5] The Royal Society, Shut Down or Restart? The Way Forward for Computing in UK Schools, Tech. Rep., 2012, pp. 1–122.
[6] R.C. Smith, O.S. Iversen, Participatory design for sustainable social change, Des. Stud. (2018) 1–28, http://dx.doi.org/10.1016/j.destud.2018.05.005.
[7] R.C. Smith, O.S. Iversen, M. Hjorth, Design thinking for digital fabrication in education, Int. J. Child-Comput. Interact. 5 (2015) 20–28, http://dx.doi.org/10.1016/j.ijcci.2015.10.002.
[8] R.C. Smith, O.S. Iversen, R. Veerasawmy, Impediments to digital fabrication in education: A study of teachers' role in digital fabrication, Int. J. Digit. Lit. Digit. Competence 7 (1) (2016) 33–49, http://dx.doi.org/10.4018/IJDLDC.2016010103.
[9] M. Hansbøl, S. Ejsing-Duun, Hovedrapport: Coding class - documentation og evaluering, in: Coding Class Report, Aalborg University, 2017.
[10] R.T. Nørgård, R.B. Paaskesen, Open-ended education: how open-endedness might foster and promote technological imagination, enterprising and participation in education, Conjunctions : Transdiscipl. J. Cult. Particip. 3 (1) (2016) 1–25.

[11] D. Ball, C. Tofel-Grehl, K.A. Searle, Sustaining making in the era of accountability: Stem integration using e-textiles materials in a high school physics class, in: Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'17, ACM, New York, NY, USA, 2017, http://dx.doi.org/10.1145/3141798.3141801, 2:1–2:7.

[12] H. Schelhowe, Digital realities, physical action and deep learning-fablabs as educational environments, in: FabLabs: Of Machines, Makers and Inventors, 2013, pp. 93–103.

[13] P. Blikstein, Digital fabrication and 'making' in education: The democratization of invention, in: J. Walter-Herrmann, C. Buching (Eds.), FabLabs: Of Machines, Makers and Inventors, Bielefield: Transcript Publishers, 2013, pp. 1–21, http://dx.doi.org/10.1080/10749039.2014.939762.

[14] P. Blikstein, D. Krannich, The makers' movement and fablabs in education, in: Proceedings of the 12th International Conference on Interaction Design and Children - IDC'13, no. April, ACM Press, New York, New York, USA, 2013, p. 613, http://dx.doi.org/10.1145/2485760.2485884.

[15] D. Passey, Computer science (CS) in the compulsory education curriculum: implications for future research, Educ. Inf. Technol. 22 (2) (2017) 421–443, http://dx.doi.org/10.1007/s10639-016-9475-z.

[16] S. Sentance, A. Csizmadia, Computing in the curriculum: Challenges and strategies from a teacher's perspective, Educ. Inf. Technol. 22 (2) (2017) 469–495, http://dx.doi.org/10.1007/s10639-016-9482-0.

[17] E. Soloway, M. Guzdial, K.E. Hay, Learner-centered design: the challenge for HCI in the 21st century, Interactions 1 (2) (1994) 36–48, http://dx.doi.org/10.1145/174809.174813.

[18] M. Scaife, Y. Rogers, F. Aldrich, M. Davies, Designing for or designing with? informant design for interactive learning environments, in: Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, in: CHI'97, ACM, New York, NY, USA, 1997, pp. 343–350, http://dx.doi.org/10.1145/258549.258789.

[19] J.A. Rode, M. Stringer, E.F. Toye, A.R. Simpson, A.F. Blackwell, Curriculum-focused design, in: Proceedings of the 2003 Conference on Interaction Design and Children, in: IDC'03, ACM, New York, NY, USA, 2003, pp. 119–126, http://dx.doi.org/10.1145/953536.953553.

[20] N. Iivari, M. Kinnula, Inclusive or inflexible: A critical analysis of the school context in supporting children's genuine participation, in: Proceedings of the 9th Nordic Conference on Human-Computer Interaction, in: NordiCHI '16, ACM, New York, NY, USA, 2016, http://dx.doi.org/10.1145/2971485.2971531, 63:1–63:10.

[21] O.S. Iversen, R.C. Smith, C. Dindler, Child as protagonist: Expanding the role of children in participatory design, in: Proceedings of the 2017 Conference on Interaction Design and Children - IDC '17, 2017, pp. 27–37, http://dx.doi.org/10.1145/3078072.3079725.

[22] O.S. Iversen, R.C. Smith, C. Dindler, From computational thinking to computational empowerment, in: Proceedings of the 15th Participatory Design Conference on Full Papers - PDC'18, ACM Press, New York, New York, USA, 2018, pp. 1–11, http://dx.doi.org/10.1145/3210586.3210592.

[23] N. Iivari, M. Kinnula, Empowering children through design and making – towards protagonist role adoption, in: PDC'18: Proceedings of the 15th Participatory Design Conference - Volume 1, Vol. 1, 2018, http://dx.doi.org/10.1145/3210586.3210600.

[24] E.-S. Katterfeldt, N. Dittert, H. Schelhowe, Designing digital fabrication learning environments for bildung: Implications from ten years of physical computing workshops, Int. J. Child-Comput. Interact. 5 (2015) 3–10, http://dx.doi.org/10.1016/j.ijcci.2015.08.001.

[25] S. Papavlasopoulou, M.N. Giannakos, L. Jaccheri, Empirical studies on the maker movement, a promising approach to learning: A literature review, Entertain. Comput. 18 (2017) 57–78, http://dx.doi.org/10.1016/j.entcom.2016.09.002.

[26] L. Martin, The promise of the maker movement for education, J. Pre-Coll. Eng. Educ. Res. (J-PEER) 5 (1) (2015) http://dx.doi.org/10.7771/2157-9288.1099.

[27] S.L. Chu, F. Quek, E. Deuermeyer, R. Martin, From classroom-making to functional-making: A study in the development of making literacy, in: Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'17, ACM, New York, NY, USA, 2017, http://dx.doi.org/10.1145/3141798.3141802, 3:1–3:8.

[28] S. Nemorin, The frustrations of digital fabrication: an auto/ethnographic exploration of '3D making' in school, Int. J. Technol. Des. Educ. 27 (4) (2017) 517–535, http://dx.doi.org/10.1007/s10798-016-9366-z.

[29] A. Berman, B. Garcia, B. Nam, S. Chu, F. Quek, Toward a making community of practice: The social aspects of elementary classroom-based making, in: Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'16, ACM, New York, NY, USA, 2016, pp. 9–16, http://dx.doi.org/10.1145/3003397.3003399.

[30] E. Tan, A.C. Barton, Designing for rightful presence in stem-rich making: Community ethnography as pedagogy, in: Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'17, ACM, New York, NY, USA, 2017, http://dx.doi.org/10.1145/3141798.3141807, 8:1–8:8.

[31] E. Eriksson, C. Heath, P. Ljungstrand, P. Parnes, Makerspace in school—considerations from a large-scale national testbed, Int. J. Child-Comput. Interact. (2017) 1–7, http://dx.doi.org/10.1016/j.ijcci.2017.10.001.

[32] D.A. Fields, Y.B. Kafai, T. Nakajima, J. Goode, Teaching practices for making e-textiles in high school computing classrooms, in: Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'17, ACM, New York, NY, USA, 2017, http://dx.doi.org/10.1145/3141798.3141804, 5:1–5:8.

[33] E. Tan, A. Calabrese Barton, M. Shin, C. Turner, Probing participatory partnerships: Equitably-consequential making by, for and with marginalized youth, in: Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'16, ACM, New York, NY, USA, 2016, pp. 1–8, http://dx.doi.org/10.1145/3003397.3003398.

[34] Swedish National Agency for Education, Curriculum for The Compulsory School, Preschool Class and School-Age Educare - Revised 2018, 2018, p. 303.

[35] Norwegian Board of Education, Core Curriculum for Primary, Secondary, and Adult Education in Norway, 1997, p. 40.

[36] Finnish National Board of Education, National Core Curriculum of Basic Education 2014, 2014, p. 473.

[37] O. Berge, Rethinking digital literacy in nordic school curricula, Nordic J. Digit. Lit. 12 (01–02) (2017) 5–7, http://dx.doi.org/10.18261/issn.1891-943x-2017-01-02-01.

[38] P. Blikstein, S.L. Martinez, H.A. Pang, Meaningful Making: Projects and Inspirations for Fab Labs and Makerspaces, Constructing Modern Knowledge Press, Torrance, CA USA, 2016.

[39] L. Ilomäki, S. Paavola, M. Lakkala, A. Kantosalo, Digital competence – an emergent boundary concept for policy and educational research, Educ. Inf. Technol. 21 (3) (2016) 655–679, http://dx.doi.org/10.1007/s10639-014-9346-4.

[40] F.M. Røkenes, R.J. Krumsvik, Development of student teachers' digital competence in teacher education - A literature review, Nordic J. Digit. Lit. (04) (2014) 250–280.

[41] F.M. Røkenes, R.J. Krumsvik, Prepared to teach ESL with ICT? A study of digital competence in norwegian teacher education, Comput. Educ. 97 (2016) 1–20, http://dx.doi.org/10.1016/j.compedu.2016.02.014.

[42] T. Bekker, S. Bakker, I. Douma, J. van der Poel, K. Scheltenaar, Teaching children digital literacy through design-based learning with digital toolkits in schools, Int. J. Child-Comput. Interact. 5 (2015) 29–38, http://dx.doi.org/10.1016/j.ijcci.2015.12.001.

[43] T.A. Dousay, An evolving makerspace for teacher education, Int. J. Des. Learn. 8 (1) (2017) http://dx.doi.org/10.14434/ijdl.v8i1.22672.

[44] J.A. Fredricks, P.C. Blumenfeld, A.H. Paris, School engagement: Potential of the concept, state of the evidence, Rev. Educ. Res. 74 (1) (2004) 59–109.

[45] T. Virtanen, Student Engagement in Finnish Lower Secondary School (Ph.D. thesis), Jyväskylä studies in education, psychology and social research 562, 2016.

[46] J.D. Finn, K.S. Zimmer, Student engagement: What is it? Why does it matter?, in: Handbook of research on student engagement, Springer, 2012, pp. 97–131.

[47] A.-j. Lakanen, V. Isomöttönen, V. Lappalainen, Five years of game programming outreach, in: Proceedings of the 45th ACM Technical Symposium on Computer Science Education - SIGCSE'14, ACM Press, New York, New York, USA, 2014, pp. 647–652, http://dx.doi.org/10.1145/2538862.2538914.

[48] S. Hidi, K.A. Renninger, The four-phase model of interest development, Educ. Psychol. 41 (2) (2006) 111–127.

[49] A.-J. Lakanen, T. Kärkkäinen, Identifying pathways to computer science: Long-term impact of short-term game programming outreach intervention, ACM Trans. Comput. Educ. (2018) http://dx.doi.org/10.1145/3283070, (in press).

[50] Danish Ministry of Education, Kommissorium for Den Rådgivende Ekspertskrivegruppe for Forsøgsprogram for Styrkelse Af Teknologiforståelse I Folkeskolens Obligatoriske Undervisning, 2018.

[51] Danish Ministry of Education, Teknologiforståelse valgfag – Fælles mæl og læseplan, 2018.

[52] K. Brennan, M. Resnick, New frameworks for studying and assessing the development of computational thinking, in: Annual American Educational Research Association meeting, Vancouver, BC, Canada, 2012, pp. 1–25, doi:10.1.1.296.6602.

[53] Y.B. Kafai, E. Lee, K. Searle, D. Fields, E. Kaplan, D. Lui, A crafts-oriented approach to computing in high school: Introducing computational concepts, practices, and perspectives with electronic textiles, Trans. Comput. Educ. 14 (1) (2014) http://dx.doi.org/10.1145/2576874, 1:1–1:20.

[54] S.B. Merriam, Qualitative Research - A Guide to Design and Implementation, third ed., Jossey-Bass, San Francisco, 2009, p. 320.

[55] L. Cohen, L. Manion, K. Morrison, Research Methods in Education, Routledge, 2013.

[56] M. Hjorth, R.C. Smith, D. Loi, O.S. Iversen, K.S. Christensen, Educating the reflective educator: Design processes and digital fabrication for the classroom, in: Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education, in: FabLearn'16, ACM, New York, NY, USA, 2016, pp. 26–33, http://dx.doi.org/10.1145/3003397.3003401.

[57] M. Kelentric, K. Helland, A.-T. Arstorp, Professional Digital Competence Framework for Teachers, Norwegian Centre for ICT in Education, 2017.

[58] C. Redecker, Y. Punie, European Framework for the Digital Competence of Educators: DigCompEdu, Tech. Rep., Publications Office of the European Unioon, Luxemburg, 2017, pp. 1–2, http://dx.doi.org/10.2760/159770.

[59] J. Pietarinen, K. Pyhältö, T. Soini, Large-scale curriculum reform in Finland – exploring the interrelation between implementation strategy, the function of the reform, and curriculum coherence, Curric. J. 28 (1) (2017) 22–40, http://dx.doi.org/10.1080/09585176.2016.1179205.