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The physical placement of classroom technology and its influences on educational practices

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The purpose of this study was to gain deeper insights into how technology restructures the classroom as a spatial setting and how the positioning of these technologies can be associated with educational practices. The research includes a photographic and schematic representation of 115 classrooms in 12 primary schools in Belgium, resulting in a typology based on structural features of the classrooms. Based on the typology derived and the specific positioning of technology, nine teachers were purposefully selected and interviewed regarding their perceptions concerning the link between the use of technology and the classroom layout. The results indicate that (1) the positioning of technology can be related to specific types of technology use; (2) the classroom layout is in transition from one central display to multiple screens; and (3) because of physical access to technology, the educational practice of individual classes is spatially dispersed over different locations within the school.

Keywords: technology; classroom layout; ICT use; primary education; case study

1. Introduction

Substantial research effort has been devoted within the field of the history of education to the material environment or the so-called materialities of schooling (Lawn & Grosvenor, 2005). Studies within this field have shown repeatedly that the basic classroom layout has remained very stable despite attempts by educational reformers, architects and school furniture designers to adjust it (cf. Herman, Van Gorp, Simon, Vanobbergen, & Depaepe, 2011). Classrooms of the nineteenth century and the first half of the twentieth century were arranged to reinforce order, discipline and school hygiene, factors considered the precondition for good educational practice reaching clear pedagogical objectives (Van Den Driessche, 2009). There were blackboards, pupil desks, educational materials stored in the cupboards, the teaching images covering the walls, etc. In these settings, the blackboard functioned to focus student attention and was the privileged place of knowledge transfer (Hertzberger, 2008).

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More recently, developments in information and communication technologies (ICT) are influencing the way educational processes are organized spatially (e.g. Brooks, Fuller, & Waters, 2012; Zandvliet, 2006; Zandvliet & Fraser, 2004). Moreover, changes in spatial organization can also be associated with changes in educational practice (Brooks, 2010). In light of this, Lim, O'Halloran, and Podlasov (2012) argue that the positioning and movement of the teacher in the classroom are fundamental to the pedagogical process. According to these authors this is an important agenda in the current age of new learning media such as digital projectors, interactive white boards (IWBs), computers and mobile devices. Finally, experts from the field of the sociology of technology describe how artifacts and physical surroundings shape the actions of the human beings using these artifacts (Bijker & Law, 1992; Borgmann, 1984). These theories make clear that human beings not only act upon the inert, material environment, but that the converse is also true. Since technological devices are mediators, they shape the behavior and the social context of their existence (Verbeek, 2005). The school architecture, the furniture and appliances allow certain kinds of actions and inhibit others (Lawn & Grosvenor, 2005).

With this in mind, we should be considering more deeply the positioning of technological devices within physical school surroundings, and how these interact with the teaching and learning activities. How is the basic layout of a classroom related to the way technology is used in teaching and learning activities? In other words, does it make a difference how the classroom layout is designed and where technological devices are located in that classroom layout? The purpose of this study is to gain deeper insight into how ICTs are positioned in schools, and how this relates to pedagogical practices. Before describing the methodology of the study, we first review the theoretical and empirical literature grounding the importance of the physical classroom layout, including the specific positioning of technology in schools.

2. Theoretical background

2.1. The positioning of technology in schools

The speed with which the revolution of technology has taken place is phenomenal. The changes have been faster than anticipated (for an overview see Lim, Zhao, Tondeur, Chai, & Tsai, 2013). Existing literature on ICT integration in primary education often focuses on factors such as children's competences with technology (Plowman, McPake, & Stephen, 2008), teachers' computer attitudes (e.g. Sang, Valcke, van Braak, & Tondeur, 2010), experience (e.g. Pamuk, 2012) and/or pedagogical beliefs (e.g. Hermans, Tondeur, van Braak, & Valcke, 2008). But without adequate recourses, there is little opportunity for teachers to integrate technology into their teaching (Voogt & Knezek, 2013). As Turbill (2001) put it, 'One computer in a kindergarten classroom is about as useful as one container with three pencils when I have 27 children in a room' (p. 175).

At the same time, new technological devices such as IWBs, computers and tablets can influence the educational space and practice (Brooks, 2010). Information is presented in different ways, pupils and students are distributed differently in space, the interaction is different in some cases, e.g. spatial arrangements like the traditional linear PC-lab may limit the pedagogy of a particular learning space (Zandvliet, 2006). According to this author, the positioning of technology within the context of a computer lab can reinforce earlier views about technology that are incongruent with the

goals for educational technology in view of twenty-first century learning (cf. Voogt & Roblin Pareja, 2012). In this respect, access to educational technology also includes the correct amount and type of technology available at exactly the sites where teachers and students can use them as envisioned (Fabry & Higgs, 1997).

Some empirical studies show that, although infrastructure is an important condition for technology integration in general, the positioning of technology in the school can also foster or hinder specific teaching and learning activities (e.g. Salomon, 1990; Tondeur, Van Keer, van Braak, & Valcke, 2008). To illustrate this, the findings of Tondeur et al. (2008) suggest that the availability of computers in a PC-lab is related to the adoption of technology to learn basic technology skills (cf. Rule, Barrera, Dockstader, & Derr, 2002), while the availability of technology *within* classrooms is positively related to the use of technology as a learning tool. Rule and colleagues (2002) show that PC-labs reduce the optimal chances for ICT integration in learning activities because of the physical separation of technology and the actual classroom (cf. Zandvliet, 2006). Moreover, Mercier, Higgins, and Joyce-Gibbons (2014) suggest that the use of technology within the classroom may be influenced by the specific location of technology in the classroom, in terms of both the learning outcomes and the interaction behaviors of students. Their findings highlight the importance of considering the learning environment when integrating ICT. The positioning is also important for specific technological devices such as an IWB, particularly where the IWB is permanently fixed (Smith, Higgins, Wall, & Miller, 2005). In their review, Smith et al. (2005) found that the IWB is often placed too high for pupils, and even teachers may have difficulty reaching the top. Interestingly, it seems that the positioning of the teacher and the IWB within the classroom determine the type of interactivity in IWB-supported lessons (see also de Koster, Volman, & Kuiper, 2013). Clearly, effectively installing technology is much more complicated than simply providing technology and securing a connection to the Internet. Important questions remain concerning how the classroom itself and the specific position of technological devices can be associated with the successful enactment of teaching and learning activities.

2.2. *Exploring the spatial layout of classrooms*

When asking how the spatial layout of a classroom can be associated with pedagogical practice (under the influence of new technologies such as computers or digital boards) it makes sense to first consider key aspects of classroom layouts (cf. Lim et al., 2012). For most people, a traditional classroom suggests a straight rectangular room (Amadeo & Dyck, 2003), a blackboard in front of strictly arranged school desks, old-fashioned didactic images covering the walls, and – notably in Belgium – a small step in front of the class symbolizing the authority of the teacher instructing his pupils (Van Den Driessche, 2009). Building on previous work of Van Den Driessche (2009), in this study we distinguish two key aspects of classroom layout to analyze the architecture of the classroom: the *location* and the *layout*.

The *location* or built environment refers to the material and geometrical form of the room. This concerns structural characteristics of the classroom. The shape of the room, walls and the restrictions posed by walls, the precise dimensions of the floor plan, the position of electrical sockets, doors, windows, their relative size etc., clearly offer opportunities or set limits for the ways in which technologies can be positioned in classrooms.

Amedeo and Dyck (2003) started with the assumption that the purpose of the specific shape of a classroom (see Figure 1) is to facilitate the activities appropriate to the location. Results from their case study suggest that teachers perceive the influences by various structural forms on teaching and learning activities to differ, but that their perceptions of such differences are mediated by their educational perspectives.

The classroom *layout* is characterized by the sub-architectural apparatus within each space (Betoret & Artiga, 2004). The arrangement of tables and chairs, projectors and screens, carpets, light sources etc., is of importance when discussing the specific positioning of technology in the classroom (see Figure 2). For example, Zandvliet (2006) observed three different but general layouts for the implementation of technology in PC-labs. There was the traditional PC-lab (linear) with rows of computers facing forward and a teaching station in the front. There was what he termed the 'peripheral lab' with computers on benches around the perimeter of a room (with students facing outwards) with other types of workspaces in the middle – more common in science classes – though this is the type of layout also seen in software developer suites. The final form was the cluster layout, which had one computer for three or more pupils working collaboratively. Also Lim et al. (2012)

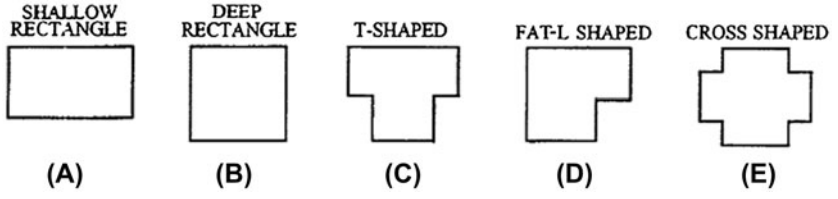

Figure 1. Five geometrical shapes of classrooms used in the study of Amedeo and Dyck (2003).

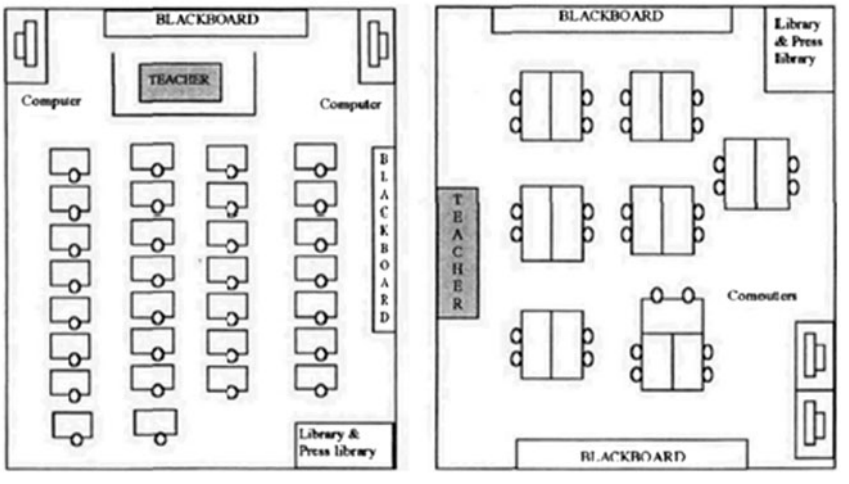

Figure 2. Two examples of classroom layouts
Source: (Betoret & Artiga, 2004).

argue that different spaces in the classroom acquire specific meanings, as well as the positioning and distance of the site relative to the students and the teaching resources, such as the interactive whiteboard and screens.

Technological devices such as computers or interactive whiteboards do not dictate one's pedagogical approach (Smith et al., 2005); rather, they enable (or hinder) the implementation of a spectrum of approaches to teaching and learning (Tondeur et al., 2008). In this respect, the rationale for school architecture lies in its 'use'. If architects speak about or design a classroom, they mainly imagine how a space could be occupied, used, inhabited (see also Hertzberger, 2008). The location and layout of classrooms is related to the pupils and teachers occupying the space. For instance, the arrangement of the school desks in single rows, in little groups, in U-shapes allows certain typical events to take place: individual study, group work, dialog, respectively. According to social agency theory, persons form relations with things. Interaction with any classroom setting occurs and then influences behavior. Questioning the intentionality of the agent (in this case – or setting) that provokes actions related to the educational use of technology brings us to the purpose of this study, *which fuels critical reflection on how the physical learning environment is currently determined and if that is desirable.*

2.3. Purpose

Much research has been conducted on the factors influencing technology integration in education. Similarly, there is no shortage of literature concerning the social environment of a classroom. Yet, even though the classroom is still one of the most important locations for school-going students, much less has been written about the spatial layout of classrooms, including the placement of technology, and the activities in certain types of settings. The purpose of this study is to gain deeper insights into how technology can be associated with the classroom layout and how the specific positioning of technologies can be associated with educational practices. The main research questions (RQ) in this study were:

- (RQ1) Can different types of classroom layouts be identified?
- (RQ2) What is the relationship between the different classroom layouts (RQ1) and the amount and placement of ICT?
- (RQ3) What is the relationship between the educational use of ICT and the placement of technological devices within these classroom layouts?

3. Research method

3.1. Sample and procedure

The data collection for this study was restricted to primary education contexts in East Flanders, a province in the Dutch-speaking part of Belgium. Stratification variables were based on the educational networks to which the schools belong, the degree of urbanization (rural/urban) and age of the school building (for an overview see Appendix). Twelve out of 15 school principals agreed to cooperate in the study, representing a high response at the school level. The sample includes 115 classrooms (including 10 PC-labs) and six different grades in 12 schools. Based on the pictures and schematic representations of classrooms studied in the sample schools,

the aim of the first phase was to identify different types of classroom layouts (RQ1). The classification of these different types is based on a schematic representation of specific features, i.e. the position of furniture in the classroom.

Following this, nine teachers were selected and interviewed (100% response rate at teacher level) about their perceptions of potential links between the educational use of technology and the classroom setting (RQ3). The selection of these teachers was based on the typology of the classroom layout and the specific positioning of the technological devices. Specifically, the teachers' classrooms represented the most common types of settings described and represented different schools. For each common type, 2–3 contrasting cases with regard to the availability and positioning of technology were selected.

3.2. Instruments and analysis

A checklist was used to portray the existing technology and furniture in each of the classrooms consistently (RQ1 and RQ2). The checklist (inventory) contained items relating to both aspects of layout described previously: the built environment and the physical infrastructure, including door(s) and windows, the seating arrangement, positioning of the chalkboard, and technological devices. Based on these results, the pictures and the schematic representation of 115 classrooms, a typology was derived according to particularly features of the classroom, namely the arrangement of desks (cf. Betoret & Artiga, 2004; Martin, 2002).

Partially derived from previous research, the interview included questioning that permitted teachers to respond in their own terms and meanings about the (relationship between the) educational use of technology and the placement of technological devices in their classroom (RQ3). Some examples of interview questions are presented in Table 1. Interviews were then transcribed, each one constituting a unique portrayal of a specific classroom.

In the first phase of analysis, the data from each teacher were synthesized and a vertical (within-case) analysis was applied (Miles & Huberman, 1994). This led to the creation of a case-specific report that organized and presented the data of each teacher, connected to his or her specific classroom. In the second phase of data analysis, the results of the vertical analysis of each case study school were submitted to a horizontal analysis or cross-site analysis (Miles & Huberman, 1994) in which data from the respondents were systematically compared for similarities and differences. During these two main stages of data analysis, the content of the within-case and cross-case analysis was discussed among the researchers to safeguard the quality of the interpretive data. All disagreements were resolved through discussion.

Table 1. Examples of interview topics and questions.

Component	Question
Use of technology	How frequently and in which situation do you use ICT in your classroom?
Flexibility of the classroom layout	How frequently do you change the composition of the pupil desks?
Didactic means and classroom layout	Does the classroom layout influence the use of different didactic means?
Use and place of technology	Are there advantages or disadvantages experienced by the place of ICT during lessons?

4. Results

4.1. Typology for classroom layouts (RQ1)

Based on the observed seating arrangements in 105 classrooms and 10 PC-labs within the 12 sample schools, this study determined seven different classroom layouts for primary education (see Figure 3): front-facing singles (Type 1), front-facing pairs (Type 2), front-facing rows (Type 3), groups (Type 4), U-shaped (Type 5), combination (Type 6) and square (Type 7). In 'front-facing singles' classrooms pupils are facing the chalkboard and are sitting individually at separate tables. Different from a 'front-facing-singles' classroom is that in 'front-facing pairs classrooms' the pupils are sitting in pairs facing the chalkboard. When pupils are facing the chalkboard in long rows we describe this as a 'front-facing rows classroom'. In a typical 'groups' classroom, pupils have eye contact and are seated facing each

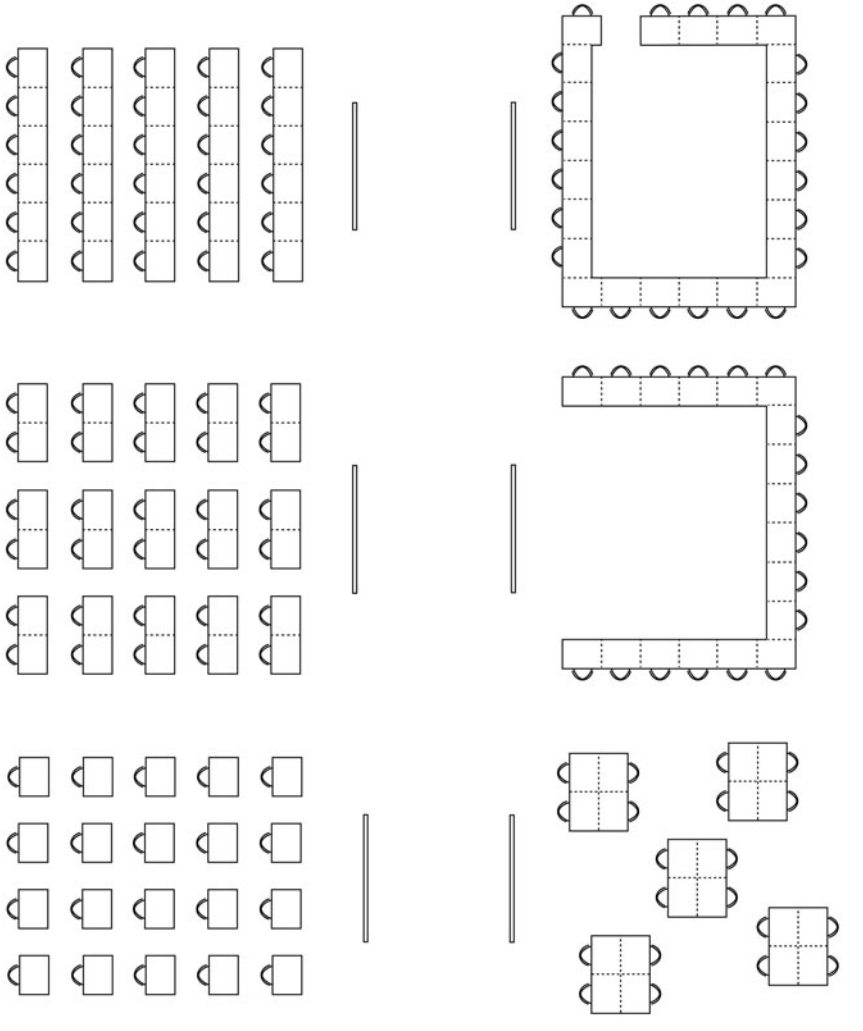

Figure 3. Typological classification of layouts in primary schools.

other in pairs, but not necessarily the chalkboard. In a 'square-classroom' all the tables are arranged in a square shape. A combination type contains combinations of all of these other types.

In the sample *classrooms* of this study, the most commonly observed layout types were: 'combination' (46%), 'front-facing pairs' (28%), 'groups' (12%) and 'front-facing rows' (11%). 'Combination' (40%) and 'front-facing rows' (30%) were the most common types of layouts for *PC-labs*.

4.2. Placement of technology in the classroom layouts (RQ2)

In this section we elaborate on the technology observed in the 105 classrooms. Almost all (98.10%) of observed classrooms contained at least one computer, i.e. desktop or laptops (see Table 2). The study observed 285 computers located within 105 classrooms. Only 3% of these were laptops. On average, each classroom had 2.77 computers (desktops and laptops) and each PC-lab 15.70 computers. Few classrooms (5%) had an interactive whiteboard (IWB) and none were observed in the PC-labs. Further, 74% of classrooms had a radio and 16% had a projector (for an overview see Table 2).

We found more computers in Type 4 'group' classrooms (M = 3.85 PCs) and Type 6 'combination' classrooms (M = 2.79 PCs) than in all other types of classrooms (for front-facing rows: M = 2.42 PCs; for front-facing pairs: M = 2.31 PCs). Most of the computers observed were mainly at the back of the classroom (49%) or at the front and back (17%). Some 80% of the interactive whiteboard (IWB) were placed in the front of the classroom.

4.3. Use and place of technological devices in the classroom layouts (RQ3)

For each common type (T) of classroom layout (T2, T3, T4, T6), contrasting classrooms in respect of the availability and positioning of technology were purposely selected. Nine teachers from these sample classrooms were interviewed about their pedagogical practice in relation to the layout (tables, technological devices, blackboard, etc.). To illustrate key distinctions on how the classroom layout and the specific positioning of technological devices can be associated with the educational uses of technology, three cases are presented below (cf. Kozma, 2003). It was decided to include one classroom from different types of classroom layout, more specifically 'front-facing rows', 'groups' and 'combination' classrooms. Also the specific positioning of the technology is different in the selected cases. In Table 3 a summary of the key findings of the nine interviews was made. The results of the horizontal analysis are integrated in the discussion section.

Table 2. Technology types observed in sample schools (n = 12).

Technology	Amount in classrooms	M	Amount in PC-labs	M
Desktop / laptop	285	2.77	157	15.70
IWB	5	4.85	0	0
Radio	76	73.79	3	30
Beamer	16	15.53	7	70
Printer	8	7.77	2	20
TV	12	11.65	1	10
DVD player	5	4.85	1	10

Table 3. Summary of the horizontal analysis of the nine sample teachers/classrooms.

School/ grade Teacher	S9/G4 Leila	S12/G4 Peter	S12/G3 Lola	S8/G6 Tom	S11/G6 Jane	S11/G3 Elsie	S8/G2 Steve	S4/G5 Lisa	S2/G6 Don
Typology	Front-facing rows	Combination	Front-facing rows	Combination	Combination (u-shape)	Combination	Front-facing pairs	Groups	Groups
Motifs	Visibility chalk board, amount of pupils, control over pupils	Variation through school year, evolution of pupils, collaboration	Amount of pupils, control over pupils	Personal choice of pupils, mobility, control and extra support	Interaction	Lesson themes, variation through school year	Visibility chalk board, control over pupils, authority	Collaboration	Directly use of PC, group work
Number of PCs	1	2	1	3	2	5	1	5	10
IWB	No	No	No	No	Yes	Yes	No	No	Yes
Computer lab	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes
Place of PCs	At the back	At the back	On the side	At the front	At the front and back	At the front and back	At the front	At the back	Entire classroom
TYPE of TECHNOLOGY USE	Differentiation, information tool, reward for good behavior	Individual practice, illustrative	Rarely used, priority pupils without PC at home, language or math tasks	Strictly used by teacher	PC at the back: contract work for pupils, PC at the front: strictly used by teacher	PC at the front for teacher use, at the back for pupil use, individual practice	Strictly used by teacher (presentations, information tool)	Individual work, contract work	Individual and group work, information tool
Motifs	Physical limitation (Internet connection), control over pupils	Physical limitation (Internet connection), not disturbing other pupils	Physical limitation (Internet connection), control over pupils	Inadequate infrastructure, pupils go to the PC-lab	Not disturbing other pupils, pupils go mostly to the PC-lab, one PC is too few for all the pupils	Physical (wires), no distraction for other pupils	Pupils go to the PC-lab	Physical limitation (Internet connection), ICT is important in lessons, motivates pupils	Directly accessible

(1) Leila's case

Leila is a 28-year-old, grade four primary school teacher with eight years of teaching experience. She works in a Catholic school (built in 1976) in a rural area. The desks in her classroom are arranged in three long rows (Type 3) which all face the board at the front (see Figure 4). Leila decided to choose a front-facing rows layout because of the visibility of the chalkboard: 'The board plays an important role in second grade when it comes to learning how to copy things correctly; many things are written on the board.' During the interview, Leila also mentioned two other reasons for this layout: (1) to see the children's faces (frontal) and (2) the large number of pupils does not allow for arranging pupils in groups. The advantage of this layout is, according to Leila, 'that when someone cannot concentrate or leave others alone, you can just take out one desk'.

As depicted in Figure 4, Leila created a sitting area in the back of the classroom where the pupils can work in groups or for differentiation. Collaboration and differentiation are also the main activities with the computer in the back corner of the classroom: 'that pupil had difficulties telling time and soon I will give him practice work in the corner'. Besides, Leila also integrates this computer as an information tool. To illustrate: 'Now we are learning provinces, we looked at Google Earth but they did so row by row, because 26 children around one computer is not feasible.' For that reason, Leila would like to have at least three computers in the classroom. According to Leila, the PC and Internet cables determine the location of the computer in her classroom. Interestingly, throughout the school, the computers are in the same corner of the classrooms. Another school policy is that in the near future there will be an IWB and laptop in the classroom. She considers this an advantage because then everything can be displayed immediately on the big screen.

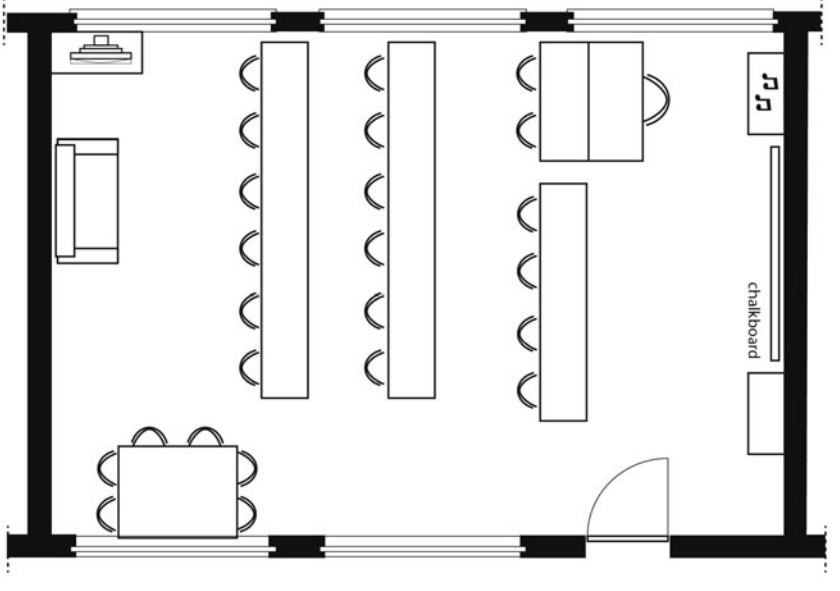

Figure 4. Classroom layout of School 9, Grade 4.

Currently, Leila must rely on the space in the back and the corridor as an adjacent classroom. In this respect, she also makes use of the PC-lab and the so-called 'digiclass'. In the PC-lab are 19 computers, a projection screen and a TV. The desks in the PC-lab are arranged in long front-facing rows. According to Leila, lessons are given in the PC-lab every other week, at a set time. Previously, the desks in the PC-lab faced the windows. This was perceived negatively because pupils had to turn if something was shown. Nevertheless, in the PC-lab the pupils particularly use the computers as a learning tool, to exercise knowledge and skills: 'The school stimulates us not to do this from one subject area – for example not just going to the computer room for world orientation but also to do math practica'.

The digiclass, including a computer, a projector and a projection screen, is used for different teaching and learning activities, with technology as a demonstration/presentation tool: 'The digiclass is looking, learning and experiencing: an oral presentation or looking at photographs of greenhouses, projects, etc.' From the results of the interview it is clear that Leila makes use of different spaces in the school resulting in different types of technology use.

> I think that what makes it the most fun is that you can vary things. Plus, I think about lack of space here in the classroom – where would they go (smiles)? If we really need to, we can look things up on our computer (in the classroom). It's not as if you can only have to send children to the PC-class.

(2) Don's case

Don is a 47-year-old grade six teacher with 24 years of teaching experience. He is allowed six hours per week to fulfill the role of ICT coordinator. He is a teacher in a publicly funded municipal school (built in 1960) in an urban area. The desks in his classroom are arranged in groups (Type 4), each with one computer available (see Figure 5). The wiring of the computers is visibly laid along the ceiling. These wiring boxes on the ceiling date back to a past life of the school, when sewing

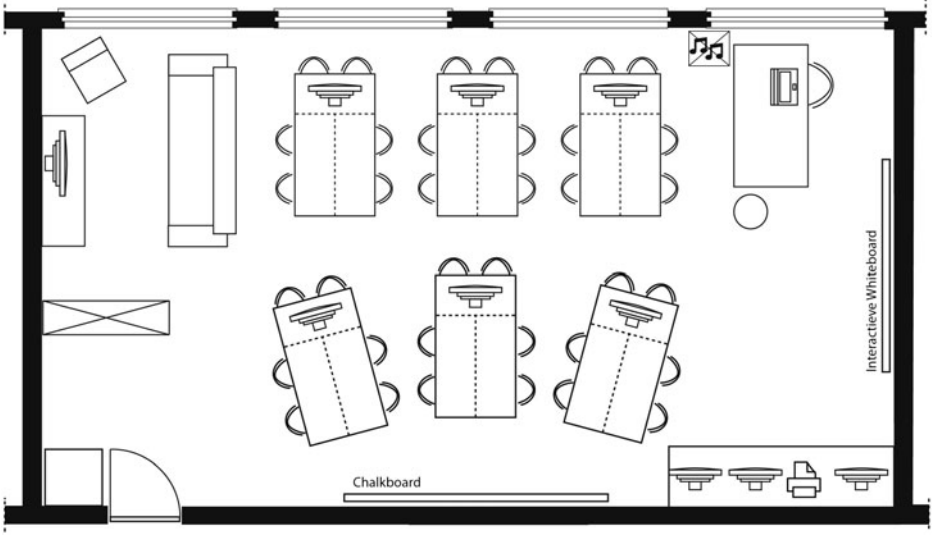

Figure 5. Classroom layout of School 11, Grade 6.

machines were in the same room. In addition, there are three computers at the side of the room. The IWB is located in front of the classroom. There are a total of 10 computers in this classroom for a total of 20 pupils.

According to Don, the classroom layout invites pupils to use computers more frequently. He has tried several classroom layouts, including rows (Type 3) or a U-shape (Type 5), but still wants the pupils together in small groups. Don prefers to have one computer for each group so they can use it in their everyday work and collaboration: 'The learners can constantly use the computer during their regular work. For example, in language, if they need to look something up, they can do that directly from their place…. Now they can also collaborate with the computer.'

A drawback of the current arrangement is that pupils sometimes get distracted by the screen when someone else is working on it: 'they have the habit of staring at the screen … and they get distracted'. Don tries to resolve this through clear agreements. The three computers at the side of the classroom 'are for occasionally working individually' or 'if someone from the group is already using the computer'. Don would like to see the computers in his class evolve to laptops with wireless Internet connection. The classroom has recently received three laptops that can be used through a rotation system. During the interview Don mentioned that his dream is:

> … to replace all the computers with laptops, so I could play around more with the desk arrangements and it would be very convenient if there were no wait time for working with the computer. The disadvantage would be that the group work would be lost. So we would need to keep an eye on that.

Since last school year there has been an IWB in the classroom but the chalkboard was retained. According to the teacher, the IWB is sometimes too far away for the pupils, given that it is a long rectangular classroom. This is solved by regularly enlarging things on the screen. Another problem is that some pupils sit with their backs to the IWB. It would be better for the pupils if the IWB was in the position of the chalkboard, but then the lighting angle would be difficult. The chalkboard is rarely used and is mostly for quickly writing things down. In contrast, the IWB 'is actually in constant use at the moment. In every lesson. For example, in the French lessons … you can click on the text and then directly hear it being read aloud by someone who has proper pronunciation.' Also the pupils make use of the IWT, e.g. 'they like to write with this pen'.

The pupils also go to the computer lab every week during a lesson period. Pupils practice individually in the computer lab what they have learned: 'Then they practice with all kinds of games on the computer there (PC-lab).' The pupils also learn technical skills in the PC-lab: 'Sometimes they have to learn how to make a presentation, work with a word processor, or learn to search the Internet in a more focused way.' It appears from the interview that Don prefers sufficient computers in the classroom (instead of a PC-lab): 'I think that it (technology use) is easier in the classroom when you have many computers. Because when other colleagues with fewer computers make the effort to go to the computer class, they go for just a few minutes.'

(3) Jane's case

Jane (26) is a sixth-grade primary school teacher in a public school in a city in East Flanders with three years' experience as a teacher (S9/K4). The school building

was constructed in 1953. The infrastructure of her 'combination' classroom (Type 6) features a combination of U-shaped, front-facing pairs and group seating arrangement (see Figure 6) for 16 pupils.

Jane argued that the U-shaped layout is an important element in her educational practice: 'learners in 4th grade must communicate a lot, they may speak their minds and that is easier when they can see each other'. The downside of the classroom layout is, according to Jane, a lack of concentration because of too much interaction. Therefore she decided to create separate areas where pupils can work independently or in small groups. Moreover, Jane changes the classroom layout according to specific lesson activities: 'during art, the desks are put together and when it is time for gym, they can be pushed aside'.

The central technological device in the space is the IWB. The teacher's personal laptop in the front of the classroom is mainly used by the teacher to control the IWB. Jane states that she uses technology more often in her educational practice due to the IWB: 'I would not be able to miss it because you can show everything through the Internet. If children ask questions like, 'Miss, I don't know what Zumba is, then: Zumba file and voila – they all know it'. Other advantages she mentioned are 'it is very easy for children to get an overview' and 'it is easy to save everything you make with this IWB'. Jane decided to keep her chalkboard as well as the IWB because 'the screen of the IWB is sometimes too small' and 'because leaving some things up on the chalkboard is also quite convenient'. The IWB is mostly used by Jane; sometimes the pupils may write something on the IWB or play a game during the break.

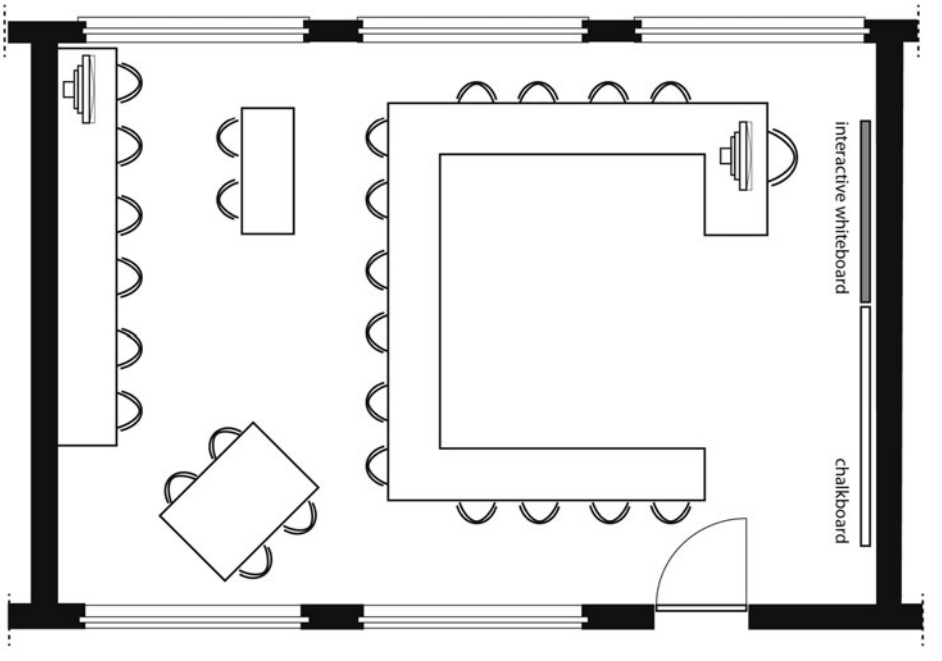

Figure 6. Classroom layout of School 2, Grade 6.

In the back corner there is a computer for the pupils but it is not frequently used because of a lack of up-to-date software. Jane prefers to let her pupils use technology for contract work, but is not able to implement this in her classroom:

> In the back I would really like to have two or three (computers). Why two or three? I use that especially for contract work and then it would be necessary for multiple learners to work simultaneously, otherwise they have to wait so very long.

To tackle this problem, Jane needs to rely on the PC-lab on a weekly basis where pupils can work individually: 'Thus we go to the PC-lab and they may do their work, for example, for French – conjugating verbs and practicing; for world orientation they look things up on the Internet, etc.'

5. Discussion and results of the horizontal analysis

More than three decades ago, Sommer (1977) stated that teachers' pedagogical beliefs are reflected in the way they arrange space, position desks and use decoration. Nevertheless, there is little empirical evidence regarding the relationships between the architectural structure of a classroom and its daily educational practice (cf. Brooks, 2010). From these scarce studies it seems that the location and layout can influence the educational processes in a positive manner. The purpose of the current study was to investigate how technology as a 'new' didactic means can be associated with the classroom layout. In the next section the results of the horizontal analysis are discussed in three parts: (1) the placement of technology in the spatial classroom layout, (2) the transition from one central display (the chalkboard) to multiple screens, and (3) the spatially dispersed classroom over different locations within the school. This next section refers to the schools (S) and grade (G) presented in Table 3.

5.1. Placement of technology in the spatial classroom layout

This study addressed the need for technology infrastructure and placement to be informed by an understanding of the extent to which the classroom layout is related to (pedagogical) decisions of the teachers. Many school buildings in Flanders and the rest of Europe date from the beginning of the twentieth century (Van Den Driessche, 2009) and, in many cases, new technologies and pedagogical practices have been forced into existing physical structures. To illustrate, eight of the 12 school buildings selected in this study were more than 50 years old (see Table 3). In these school buildings the determined typology of classroom layouts had similarities to other theories that also presented 'front-facing singles, pairs and rows' and 'group' classrooms (cf. Betoret & Artiga, 2004; Martin, 2002). The only difference from the Martin (2002) study is the absence of an arrangement of desks in a circle.

Betoret and Artiga (2004) found in their study that the classroom layout is closely related to teachers' practice. The findings of the horizontal analysis in this study confirm that different teaching and learning activities can be related to specific classroom layouts. For instance, the 'group' arrangement invites pupils to collaborate (S2/G6), the 'combination' arrangement allows the teacher to switch to different activities (S11/G3), etc. But in contrast to the assumption that the specific shape of a classroom is to facilitate the activities appropriate to the location (e.g. Amedeo & Dyck, 2003), it seems that teachers in the current study were more limited to the

material or geometrical form of the room. Some of the teachers (e.g. S9/G4) preferred more computers in the classroom and/or a different layout, but were restricted because of the size of the room.

Apart from the layout in the observed and interviewed classrooms, the positioning of technology also seems to be related to the way the educational process is organized (cf. Tondeur et al., 2008). Don for instance prefers to have one computer for each group so the pupils can use it in their everyday work and collaboration (S2/G6), while the only computer in the back of Jane's class is used for contract work (S11/G6). Fisher (2005) went so far as to propose a range of pedagogies that could be used, depending on the subject matter, to support a range of student skills and competences that could be linked to particular spatial configurations that lent themselves well to these learning activities. Teachers in our study also chose technological devices for specific places in the classroom for more practical reasons: visibility of the IWB (cf. Smith et al., 2005) and blackboard (S9/G4, S8/G2), number of pupils (S9/G4, S12/G3), characteristics of the pupil group (S12/G4, S11G3), concentration and attention (S9/G4, S8/G2) etc. In this respect, we refer to the classroom layout as an action context: 'interaction with our environment is part of our interaction with others' (Canter in van Kooten 1988, p. 19). Consequently, the layout of a classroom is not a given but the result of 'mediating agencies' (Herman et al., 2011).

Nevertheless, in the rush to implement technology, teachers and schools may have perpetuated a largely unquestioned view that technologies are to be implemented in 'techno-centered PC-labs' (Zandvliet, 2006). In this study, six out of nine teachers make use of a PC-lab, but mostly for drill and practice exercises. This confirms that the PC-lab is not the space in which to use ICT for twenty-first century learning (cf. Voogt & Roblin Pareja, 2012). At the same time, the results of this study show that although 10 out of 12 schools in this study have a PC-lab, the teachers in these schools prefer to have (more) computers in their classrooms (instead of a PC-lab). In line with the study of Tondeur et al. (2008), it seems that decisions concerning the specific positioning of technology are determined at the school level (cf. S9/G4). In this respect, Laferrière, Hamel, and Searson (2013) learned that teachers want to have their say regarding hardware (e.g. when IT personnel did not consult teachers on the arrangement of computers in the classroom).

5.2. *From one central display to multiple screens*

From the background of this study it is clear that the ideal typical layout of the traditional classroom is related to relatively unambiguous educational practices. In the history of architecture of the classroom the attention is directed to the blackboard, the first and most important display within the room (Van Den Driessche, 2009). In such 'typical' classrooms, school desks are oriented towards this screen and towards the teacher in front of the class (cf. S9/G4, S8/G2). The architecture of the classroom was conceived to support the educational situation centered on this central place of display.

However, new didactical means and the new technologies seem to influence this disposition. Even within the rigid geometry of the traditional classrooms in the sample schools, different sorts of situations emerged. In the classrooms analyzed, multiple screens appeared: for instance small cozy corners were observed (S12/G4, S4/G5), desktops on each desk (cf. S2/G6), an IWB in front of the classroom (cf. S11/G6), etc. As a result, the attention of the group is split among different foci. In

this situation the dimensions of the screen and the precise location of these devices are then of major importance. The size of the screen begins to define groups within a classroom, along with the working methods and possible educational practices, even more than the geometrical form of the classroom (cf. Smith et al., 2005). At the same time, some teachers consider the distraction of the screen for pupils to be a drawback (S9/G4). In this respect, some of the interviewed teachers (S11/G6) decided to 'hide' the computer in the corner of their classroom. As such, the technology is separated so as not to disturb the teaching/learning activities.

5.3. The dispersed classroom

In the 12 sample schools, reorganization of the educational space due to technology integration was explored. Sometimes less appropriate spaces outside the classroom such as corridors or small storage rooms were used to place computers for individual work (see e.g. S4/G5). Nine out of 12 schools have different special rooms to accommodate the new technology: a digital class, a computer room, or a media lab. These special rooms have their own specific equipment and the inhabitants go to these rooms on particular occasions. Consequently, the educational practice of individual classes is also dispersed over different locations within the school. Since the entire school building is used differently, the regime of the school itself has been reconsidered (Van Den Driessche, 2009).

Since the traditional classroom often seems unsuitable to include new technologies and support contemporary educational practices, we could ask ourselves how a new school building should look. Burke and Grosvenor (2008) argued that:

> If schools are to continue to exist well into the twenty-first century they need to be more fulfilling, more creative and more humanly attentive places than they have been thus far, both for those who teach in them and for those required to attend them. (Burke & Grosvenor, 2008, p. 159)

In radical school projects today, a rigidly delimited room sometimes even dissolves to make place for an arrangement of chests and carpets defining functional, but only softly materialized learning zones. Pupils may arrive with their laptops or tablets and connect to wireless networks all over the learning space. The UBIKO school at the Oulu University Teacher Training College in Finland represents one such project, where architects, educators and researchers are working together to create spaces conducive to developing twenty-first-century skills.

It is also clear that educators need to conceive of these new school buildings beyond the classroom itself. A more substantial understanding of the layered architecture of the classroom may give some clues to rethink the school building in its totality, including the role of technology. Therefore, choices have to be made in terms of educational objectives (Hermans et al., 2008). In this respect, Radcliffe (2008) provided a tool that uses the relationship between pedagogy, space and technology in order to inform the design, operation and assessment of learning spaces, each of the three elements influencing each other in a reciprocal manner. It emphasizes the importance and arrangement of space to influence patterns of teaching and learning. According to Radcliffe (2008) the 'learner' is an active participant inside the 'pedagogy–space–technology' triangle, influencing – and being influenced by – these elements according to the situation and context. This relationship is

important as the evidence suggests that technologically enhanced learning environments, independent of all other factors, seem to have a positive impact on student learning (Brooks, 2010).

5.4. Limitations of the study and directions for future research

This study used a case-study approach to explore the importance of the classroom layout and how the specific positioning of technologies can be associated with educational practices. The analysis of pictures and schematic representations of classrooms studied, in combination with in-depth interviews, provided a deeper, richer account and a broader context than can be obtained by a large-scale survey. However, the results of this study cannot simply be generalized to other educational levels. Some classroom-related characteristics are specific for the context of primary education. In secondary and higher education both the specific positioning of technology in schools and the use of technology in teaching and learning processes might be different.

Furthermore, we have to assume that the uses and positioning of technology in classrooms can be different in different parts of the world. Perhaps in some countries teachers and pupils make more use of laptops or tablets. However, while mobile technologies are often used at home and in the office, and we experiment with them in schools, it will be years before the classrooms are dominated by mobile technologies (see e.g. Pynoo, Kerckaert, Goeman, Elen, & van Braak, 2013). But even when they are, the conceptual considerations related to the classroom environment this study raises are still relevant and can also be related to the integration of mobile technologies. To illustrate, in a recent study on mobile technologies, Sølvberg and Rismark (2012) described how students engaged in learning activities within different learning spaces. Each learning space had different features which became visible when exploring how the students worked with the course material. This is in line with the findings of the current study, suggesting that the educational practice of individual classes is dispersed over different locations within the school, each with specific educational objectives. One major asset of mobile technologies in the study of Sølvberg and Rismark (2012) was the flexibility of being able to study at any time and any place. Future work on ICT in the classroom will expand to consider how teachers manage new (mobile) devices within the different room configurations (cf. Lui & Slotta, 2014; Mercier et al., 2014).

The results presented in this study fuel the development of descriptive theory concerning the complex relationship between the classroom layout and the educational practice, with a special focus on technology. We can think of ICT as a physical property that is always relative to something and, in the context of ICT in education, relative to desirable goals or strategies for teaching and learning (Hammond, 2010). According to this author, the description of ICT in the physical classroom setting is socially constructed. Future research should therefore consider the use of space through positioning and movement of the teachers (cf. Lim et al., 2012) and pupils. Observing teachers and pupils can be a promising approach to help refine the initial findings presented in this study. Also a longitudinal study looking at the effects of change where the physical environment is infused with carefully designed digital tools and materials to support student interactions could lead to new insights (see, e.g., Lui & Slotta, 2014). Finally, to explore if and how schools can realize such changes, research is needed into the effects of the classroom interior

design process on teachers' and learners' locus of control with respect to ICT integration. However, the relationship between people and their environment is complex and therefore any outcomes from a change in setting are likely to be produced through an involved chain of events (Woolner, Hall, Higgens, McCaughey, & Wall, 2007). It is the defining and understanding of these mediating chains that is key and must take account of issues relating to ownership, relevance, purpose and permanence.

6. Conclusion

This study has initiated an important step in an emergent area of inquiry: gathering empirical evidence on the relationship between the place of technology in schools and specific teaching and learning practices. The scarcity of empirical research to date seems to imply that the positioning of technology in schools might be better left to school designers, architects or ICT coordinators than teachers, and that teachers should confine their concerns to issues of pedagogy and curriculum. This study has questioned such a perspective and has looked at the 'ecology' of educational spaces as they are informed by place, pedagogy, design and the integration of new technologies.

After the survey on the use of digital technologies in the sample schools we can make some further conclusions. First, it is apparent that space can be a partner within pedagogy, and such a partnership is precisely what could be interesting when we consider ICT integration in education. But at the same time, space was also perceived in this study as a barrier: the traditional classroom seems often unsuitable to include new technologies. Second, the layout of the classroom, including the positioning of technology, can be clearly related to specific teaching and learning activities. In this respect, technological devices do not embody one single pedagogical orientation; instead they enable the integration of a spectrum of approaches to teaching and learning. Based on the findings of this study, we conclude that not only the technologies themselves, but also their physical placement in the overall classroom layout mediates their pedagogical usage. These kinds of decisions deserve to be carefully considered, not determined by happenstance, as is frequently the case. Further research is needed to help architects, school leaders and teachers make informed decisions regarding classroom layout and technology placement.

References

Amedeo, D., & Dyck, J. A. (2003). Activity-enhances arenas of designs: A case study of the classroom layout. *Journal of Architectural and Planning Research, 20*, 323–343.

Betoret, F. D., & Artiga, A. G. (2004). Trainee teachers' conceptions of teaching and learning, classroom layout and exam design. *Educational Studies, 30*, 355–372.

Bijker, W. & Law, J. (Eds.). (1992). *Shaping technology/building society.* Cambridge, MA: MIT press.

Borgmann, A. (1984). *Technology and the character of contemporary life*. Chicago, IL: University of Chicago Press.

Brooks, C. D. (2010). Space matters: The impact of formal learning environments on student learning. *British Journal of Educational Technology, 42*, 719–726.

Brooks, R., Fuller, A., & Waters, J. (2012). *Changing spaces of education: New perspectives on the nature of learning*. New York, NY: Routledge.

Burke, C., & Grosvenor, I. (2008). *School*. London: Reaktion Books.

Fabry, D. L., & Higgs, J. R. (1997). Barriers to the effective use of technology in education: Current status. *Journal of Educational Computing Research, 17*, 385–395.
Fisher, K. (2005). Research into identifying effective learning environments. *Evaluating Quality in Educational Facilities, 9*, 159–167.
Hammond, M. (2010). What is an affordance and can it help us understand the use of ICT in education? *Education and Information Technologies, 15*, 205–217.
Herman, F., Van Gorp, A., Simon, F., Vanobbergen, B., Depaepe, M. (2011). Modern architecture meets new education. Renaat Braem's design and the Brussels Decrolyschool (1946). *Belgisch Tijdschrift voor Nieuwste Geschiedenis, XLI*, 135–166.
Hermans, R., Tondeur, J., van Braak, J., & Valcke, M. (2008). The impact of primary school teachers' educational beliefs on classroom use of computers. *Computers & Education, 51*, 1499–1509.
Hertzberger, H. (2008). *Space and learning*. Rotterdam: 010 Publishers.
van Kooten, T. (1988). *Ruimte op school* [Space in school buildings]. Groningen: Wolters-Noordhoff.
de Koster, S., Volman, M., & Kuiper, E. (2013). Interactivity with the interactive whiteboard in traditional and innovative primary schools: An exploratory study. *Australasian Journal of Educational Technology, 29*, 480–495.
Kozma, R. (2003). *Technology, innovation, and educational change: A global perspective*. Eugene, OR: International Society for Technology in Education.
Laferrière, T., Hamel, C., & Searson, M. (2013). Barriers to successful implementation of technology integration in educational settings: A case study. *Journal of Computer Assisted Learning, 29*, 463–473.
Lawn, M., & Grosvenor, I. (2005). *Materialities of schooling: Design, technology, objects, routines*. Oxford: Symposium Books.
Lim, F. V., O'Halloran, K. L., & Podlasov, A. (2012). Spatial pedagogy: Mapping meanings in the use of classroom space. *Cambridge Journal of Education, 42*, 235–251.
Lim, C. P., Zhao, Y., Tondeur, J., Chai, S. C., & Tsai, C. C. (2013). Bridging the gap: Technology trends and use of technology in schools. *Journal of Educational Technology & Society, 16*, 59–68.
Lui, M., & Slotta, J. D. (2014). Immersive simulations for smart classrooms: Exploring evolutionary concepts in secondary science. *Technology, Pedagogy and Education, 23*, 57–80.
Martin, S. H. (2002). The classroom environment and its effects on the practice of teachers. *Journal of Environmental Psychology, 22*, 139–156.
Mercier, E. M., Higgins, S. E., & Joyce-Gibbons, A. (2014). The effects of room design on computer-supported collaborative learning in a multi-touch classroom. *Interactive Learning Environments,* 1–19.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage.
Pamuk, S. (2012). Understanding preservice teachers' technology use through TPACK framework. *Journal of Computer Assisted Learning, 28*, 425–439.
Plowman, L., McPake, J., & Stephen, C. (2008). Just picking it up? Young children learning with technology at home. *Cambridge Journal of Education, 38*, 303–319.
Pynoo, B., Kerckaert, S., Goeman, K., Elen, J., & van Braak, J. (2013). MICTIVO: Monitoring ICT integration in Flemish education: Theoretical background and set-up. *15th biennial EARLI conference for research on learning and instruction (EARLI-2013)*.
Radcliffe, D. (2008). A pedagogy-space-technology (PST) framework for designing and evaluating learning places. Paper presented at the Learning Spaces in Higher Education: Positive Outcomes by Design: Proceedings of the Next Generation Learning Spaces 2008 Colloquium, Brisbane.
Rule, A. C., Barrera, M. T., Dockstader, C. J. & Derr, J. A. (2002). Comparing technology skill development in computer lab versus classroom settings of two sixth form grade classes. *Journal of Online Interactive Learning, 1*, 1–11.
Salomon, G. (1990). The computer lab: A bad idea now sanctified. *Educational Technology, 30*, 50–52.

Sang, G., Valcke, M., van Braak, J., & Tondeur, J. (2010). Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors with educational technology. *Computers & Education, 54*, 103–112.
Smith, H. J., Higgins, S., Wall, K., & Miller, J. (2005). Interactive whiteboards: Boon or bandwagon? A critical review of the literature. *Journal of Computer Assisted Learning, 21*, 91–101.
Sølvberg, A. M., & Rismark, M. (2012). Learning spaces in mobile learning environments. *Active Learning in Higher Education, 13*, 23–33.
Sommer, R. (1977). Classroom layout. *Theory into Practice, 16*, 174–175.
Tondeur, J., Van Keer, H., van Braak, J., & Valcke, M. (2008). ICT integration in the classroom: Challenging the potential of a school policy. *Computers & Education, 51*, 212–223.
Turbill, J. (2001). A researcher goes to school: Using technology in the kindergarten literacy curriculum. *Journal of Early Childhood Literacy, 1*, 255–279.
Van Den Driessche, M. (2009). *Architecture of the educational complex in the Belgian context*. (Unpublished doctoral thesis). University Ghent.
Verbeek, P. P. (2005). *What things do? Philosophical reflections on technology, agency and design*. University Park, PA: Pennsylvania State University Press.
Voogt, J., & Knezek, G. (2013). Building a global community of policymakers, researchers and educators to move education systems into the digital age. *Journal of Computer Assisted Learning, 29*, 399–402.
Voogt, J., & Roblin Pareja, N. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*, 299–321.
Woolner, P., Hall, E., Higgins, S., McCaughey, C., & Wall, K. (2007). A sound foundation? What we know about the impact of environments on learning and the implications for Building Schools for the Future. *Oxford Review of Education, 33*, 47–70.
Zandvliet, D. (2006). *Education is not rocket science: The case for deconstructing computer labs in schools*. Rotterdam: Sense Publishers.
Zandvliet, D., & Fraser, B. J. (2004). Learning environments in information and communications technology classrooms. *Technology, Pedagogy and Education, 13*, 97–123.

Appendix. Information about the sample schools

School	Degree of urbanization	Educational network	Year of construction
S1	Urban	Subsidized free school	1905
S2*	Urban	Subsidized free school	1960s
S3	Urban	Subsidized public schools	1979
S4*	Urban	Government-provided education	1950–1960
S5	Rural	Subsidized free school	Old buildings: unknown; new building: 2003
S6	Rural	Subsidized free school	Old buildings: unknown; new building: 2007
S7	Urban	Publicly funded, publicly run education	1924; new wing: 2010
S8*	Rural	Publicly funded, publicly run education	Wing 1: renovated in 1975; Wing 2: 1975
S9*	Rural	Subsidized free school	1976
S10	Rural	Subsidized free school	Unknown
S11*	Urban	Government-provided education	1953
S12*	Urban	Subsidized free school	1875 (former monastery)

Note: *Schools selected for the interviews.