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Finding space for technology: Pedagogical observations on the organization of computers in school environments

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Abstract

Abstract: With the large-scale acquisition and installation of computer and networking hardware in schools across Canada, a major concern has been where to locate these new technologies and whether and how the structure of the school might itself be made to accommodate these new technologies. In this paper, we suggest that the physical location and organization of computer technologies, whether in the lab, classroom, library, or even school hallway, delimits and shapes the ways in which teachers talk about and make use of computers in their schools. As with the distribution of and access to any kind of resource, the distribution and organization of computers has an impact on the frequency and quality of teachers' integration/implementation efforts. We focus on three case studies that highlight how the structuring and re-structuring of space in schools can be a significant factor in whether and how this technology is used by teachers and students.

Résumé: Avec l'achat et l'installation à grande échelle d'ordinateurs et de composantes de réseaux dans les écoles de l'ensemble du Canada, nous avons été préoccupé par l'endroit où installer ces nouvelles technologies et à déterminer si et comment la structure de l'école pourrait loger ces nouvelles technologies. Dans cet article, nous suggérons que l'emplacement physique et l'organisation des technologies informatiques, que ce soit en laboratoire, en salle de classe, à la bibliothèque ou même dans les couloirs de l'école, délimite et dirige de quelles façons les enseignants parlent de leurs ordinateurs et utilisent leurs ordinateurs dans leur école. Comme pour la distribution de n'importe quelle ressource ou leur accès, la distribution et

l'organisation des ordinateurs ont des répercussions sur la fréquence et la qualité du travail d'intégration et de mise en place des enseignants. Nous nous concentrons sur trois études de cas qui soulignent à quel point l'organisation et la réorganisation de l'espace dans les écoles peuvent être des facteurs importants pour déterminer si et comment cette technologie sera utilisée par les enseignants et les élèves.

Overview

The large-scale acquisition and installation of computer and networking hardware in schools across Canada has forced administrators and teachers to address two significant concerns. First, where to locate these new technologies: in computer labs, classrooms, libraries or mobile laptop labs. Second, whether the architectural structure of the school (i.e., classroom size and shape, including desks that accommodate mobile laptop technology, the building of new labs and/or the creation of computer libraries) needs to be altered to accommodate new technologies. Cost factors often determine the placement of computers in schools, as the price of rewiring an older school to equip classrooms with networking and internet capabilities can be excessive and not easily afforded by schools. The access to and location and allocation of computers is a complex financial consideration for schools, their administrators, and technical support staff. Teachers, on the other hand, are faced with demands by provincial policy-makers to make educational use of these new tools, often without any discussion of the teaching and learning issues around computer-use (Cuban, 2001; de Castell, Bryson, & Jenson, 2002; Norris, Sullivan, Poirot, & Soloway, 2003).

There is little doubt that most schools experience the introduction of computers as institutionally disruptive and structurally demanding; it is only since the mid 1980s that schools have been intentionally designed and built to accommodate such technological demands. In most schools, the installation of computers has meant that space must be "found" or "given up," which can require significant institutional restructuring – as one teacher we interviewed remarked, "we gave up our music room to have a computer lab, now we don't even have music anymore because there is nowhere to send the students." Debates on where to place computers in schools have centered on access and use: will students have greater access to computers in a lab setting or in the classroom? Where will teachers dedicate more time to computer use – lab or classroom? Where should computers be located to support teachers as they integrate technology into their curriculum? And, because all too often computers in labs and classrooms are viewed as being under-utilized, is the physical location of the computers contributing to their under use?

Typically omitted from this list are questions about teaching and learning, that is, questions which ask whether and how computer location/placement might limit, change, enable, or disable different kinds of pedagogy and possibilities for teacher practice. This article addresses the pedagogical implications of the relationship between seemingly basic decisions about where to put computers in schools and the way in which those computers are used.

While the school-based organization of technologies was *not* the primary subject of this study, in each of the thirty-two schools visited in six different provinces across Canada the institutional organization, structure and use of space in the placement of computers within the school figured prominently in whether and how teachers made use of computers with their students. More importantly, teachers and administrators often had strong opinions about how much and in what ways the school location of computer technology mattered in the work of education. In each of the interviews, physical location and access to the technological resources already available in the school was frequently cited as one of the most important factors in shaping how teachers were integrating technology into their curriculum and instruction (Norris, et al, 2003; Sharples, 2002; Swan, van 't Hooft, Kratcoski, & Unger, 2005).

This article considers how the structuring and re-structuring of space for computers in schools was an important factor in whether and how they were used by teachers and students. The examples we give are not intended as prescriptions for how schools ought or ought not to organize the physical layout of their technological resources. Rather, these illustrations are meant to serve as sites for exploring the *direct* and *symbolic* influences of existing and emergent patterns of organizing school computers, based either on their use, or lack thereof. In the first example, which illustrates the "classroom versus lab" debate, the commitment to a single direction can limit, restrict and sometimes make impossible the use of computers for some teachers in the school. In the second example, where computers are located in diffuse sites across the school or can be moved easily between locations, it is demonstrated that organizational flexibility can contribute to school-wide integration efforts. The third example explores the frontier of new school design and illustrates how teachers' and students' use of technology can be supported by a school's architecture and the location of computers within it.

Exploring the impact of technology placement on its pedagogical uses was not the direct focus of the research project from which this data is derived. However, the significance of the issue emerged as a result of observations at thirty-two school sites and conversational (rather than "formal") interviews. At each of the sites, eight to twelve hours were spent speaking with the administration, teachers and (in some cases) students, as well as by making direct observations in classrooms, in labs, and anywhere else technology was placed within the school. Interviews were either audio-recorded or were recorded in note form at the time of the interview and written up following the site visit as field notes. All observations were recorded in field note format. The (somewhat) anecdotal quality of the empirical data we present here does not detract, we think, from the significance of these insights, so much as it emphasizes the need for more sustained inquiry into how the physical organization of computers in schools (dis)allows certain pedagogical possibilities.

The influences of classroom design and organization on student and teacher behaviour have been documented as both *direct* and *symbolic* (Green, Cook, & Bolt, 1996; Weinstein, 1981). In a classroom where the students' desks are organized in straight rows facing forward, one of the *direct* influences of the classroom's physical layout is to make group

discussion difficult, if not impossible because the students cannot face each other or hear each other speak. In this same example, the *symbolic* influence can have a similar causal effect of dissuading class discussion: sitting in straight rows suggests to the students that the teacher does not value class participation and that students are not meant to interact.

The introduction of new technologies into classroom spaces also alters student and teacher behaviours (Becker, 1999; Cuban, 2001; Dwyer, Ringstaff, & Sandholtz, 1990a, 1990b; Goldberg, Russell, & Cook, 2003; Sandholtz & Reilly, 2004; Sandholtz, Ringstaff, & Dwyer, 1997; Swan, et al., 2005). Certainly the integration of technology in schools has always had a pedagogical focus, and that focus has often been placed on how the location of the technology affects the *quantity* and frequency of use (Bebell, Russell, & O'Dwyer, 2004; Hernandez-Ramos, 2005; Ravitz, Wong, & Becker, 1998, 2000; Silvernail & Lane, 2004). The work of this research indicates that the physical location/organization of the technology also reflects and shapes the *qualitative* possibilities for use.

Although efforts have been made to link technology to the curriculum in pedagogically sound ways, issues of how computers should be organized within the given space of the classroom to promote curricular integration efforts are often neglected due to the practical difficulties faced by schools just trying to find space for this new technology. There have been a number of studies (Gayeski, 1995; Glass, 1997; Green, et al., 1999; Najmi, 1996) that address how computers might most optimally be placed in classrooms and labs, taking into consideration not only the layout of the room but also environmental issues such as lighting and ergonomics. That said, schools are still very much constrained by some of the following issues:

1. *Working conditions:* such as optimal lighting or ergonomics for sitting, writing, reading or listening, are not sufficiently addressed;
2. *Purchasing decisions and location of new technologies:* often constrained by district specifications and costs, with little input from "end users" (i.e., teachers and students);
3. *Overcrowding:* classrooms / schools often support more students per class than these were originally designed for; and
4. *Bricks and Mortar:* all but the most recently built schools were not designed to accommodate new computer-based technologies which take up already limited physical space and demand infrastructure support in terms of cabling and electrical wiring.

Given these constraints, discussions around optimal arrangement of computers in labs and classrooms to support both teaching and learning rarely take place. In all of the older schools that were visited (approximately 27 of 32), the placement of computers was not only constrained by the availability of space (in both labs and classrooms), but also the availability of adequate and appropriate furniture, electrical outlets, and network/Internet drops. Computer equipment often ends up being located based on its minimum space requirements – for example, along the non-blackboard wall (Glass, 1997) – rather than on pedagogical considerations.

Whether or not pedagogical considerations were sufficiently addressed by schools in the organization of computer technology, it was interesting to discover that the location of computer technologies – in a lab, classroom, library, or even school hallway – shaped the

ways in which teachers talked about and made use of computers in the schools visited. As with the distribution and access to any kind of resource (which for many of the schools visited could be labelled "scarce"), the distribution of and access to computers had a range of effects on integration/implementation efforts of the teachers who were interviewed for this project.

The structural demands for cabling could dramatically change, of course, with the increased use of wireless networks and as could the physical, special demands decrease with the increased use of laptops.

Singular Commitment: Dismantling a Computer Lab

There are obvious and well-documented advantages and disadvantages regarding the use and placement of computers in labs and/or classrooms. At the same time, there is little agreement in the literature on this debate that has spanned nearly two decades (see, for example, Becker, 1984; Beers, Paquette, & Warren, 2000; Najmi, 1996; Smerdon, et al., 2000; Wilson, 1993). Placing computers in a lab setting allows for more direct instruction of large groups/classes and for whole classes to work on the same project at once. Such arrangement enables skills-based training in an individual, one-person per machine learning environment. Computer labs also have their disadvantages: teachers and students might have infrequent access to the lab; they disrupt their classroom routine to make use of the lab; and labs require frequent and higher-skilled maintenance (Bauer & Kenton, 2005; Becker, 1999; Cuban 2001; Fulton & Sibley, 2003; Shamburg, 2004).

Placing computers in classrooms, on the other hand, gives teachers and students ready access to equipment, encourages daily, ongoing use of the technologies and encourages a more project-based and cooperative approach to computer use (i.e., classroom computers must be shared by all students). However, teachers often complain that there are either not enough machines per classroom or the whole class cannot work on the same project at once. Space in the classroom is already highly limited and the placement of computers can restrict other uses of the learning environment. Further, student access to computers in a classroom cannot necessarily be characterized as "frequent," as many of the teachers interviewed claimed to use their classroom computers as a "reward" and little else.

At most of the schools that were visited (over half), teachers referred to the tension between locating school computers in one large "pod" as in a computer lab or library and distributing them in smaller pods of two or three among individual classrooms. Regardless of individual strategies at each school, it seemed that the classroom versus lab debate had been considered by most school staffs at some point in the deliberation process. In addition, the large pod versus small pod question has been taken so seriously in some provinces and school districts that it has shaped the discussion as well as the kinds of policy being implemented at the school-level.

Educational policy in one Western Canadian province, for example, requires that teachers make integrated use of computers with their classes, focusing on computers as "just another [learning] tool". Understandably, then, in one rural school visited in that province,

the school administrator and teachers were committed to the idea that computers were "just another tool," and had consequently, two years prior to our visit, dismantled their computer lab and moved computers into the classrooms. During the visit, the principal and teachers spoke at length about the practical implications of this policy on their own practices and uses of computers with their classes. Worthy of note in the following accounts are the perceptual differences between the policy-maker (the principal) and those whose practices the policy effects (the teachers).

The Administrative Perspective

Watson Elementary is a rural school with 300 students in grades K-7. At the time of the study (October 2000) David had been the principal at Watson for two years. At the beginning of his tenure, the district recommended to schools that they dismantle their computer labs and put all computers directly into classrooms. David took this recommendation seriously by instituting the change and, he admits, without consulting the teachers.

Notwithstanding opposition from his staff, David was committed to leaving the computers in classrooms. He explained that with a lab and 18-20 classrooms, the students were only able to use the computers once a week; further, there was the tendency to teach computers as a "separate" subject. With two to four computers in each classroom, he felt that teachers would change their teaching style to accommodate greater computer use and, accordingly, the greater exposure suggested that students were more likely to use the computers.

Echoing the language of the mandate of the provincial government to use computers as "just another learning tool" and as a tool to "enhance learning for a particular subject area," David observed that some, though not all of the teachers in the school, showed greater success at integrating computers in their curriculum with the placement of computers in their classrooms. When asked how he was encouraging and/or providing support for those teachers who still were not using computers with their classes, David indicated that while some computers "collected dust", as a principal he was committed to "finding gadgets" to spark interest. The presence of policy language in the discussion and the implications on perceptions and possibilities for the technology is worth mentioning. Using the school budget, David hoped to encourage classroom use of technologies by buying "gadgets" that the teachers were interested in learning to use, such as scanners, microscopes, a "white board" and digital cameras. He also tried to give teachers time to plan with the librarian, whom he said really helped the teachers to implement technology in their classes.

All names of participants and schools involved in this study have been changed in order to protect their identities.

Teachers' perspectives: Flexibility rather than singularity

In marked contrast to the principal's enthusiasm for the changes and potential made possible through a dismantling of the computer lab, the teachers at Watson were less

certain about the benefits of this change. Four out of five teachers expressed disappointment that there had not been some consultation before the decision had been made. Faced with the daily realities and constraints of attempting to make thoughtful, educative and effective use of computers with their students, the teachers at Watson were also ambivalent as to whether or not having the computers in their classes instead of the lab promoted greater computer-usage.

One teacher described a positive result of the change by saying that having the computers in her class had "changed her style of delivery" – that is, she thought "less linearly" and more about problem-solving with her students. In contrast, each of the five teachers confirmed that one of the more negative results of the dismantling of the computer lab was that it made project-based work for the whole class extremely difficult. In order to give all students in a classroom access to computers, teachers had to "farm" their students out to other classrooms, which hindered the students' collective work and was disruptive for other teachers and their classrooms.

Committing all of their technological resources, as Watson did, to a singular approach by eliminating the school's computer lab, obviously limits what is possible for instruction and learning how to use the machines. Instead, what principals, teachers and district administrators might do well to remember is that a more flexible or diversified approach to the organization of computer technology that moves past the binary "computer versus lab" debate, in consultation with teachers, could provide more consistent support for the various instructional uses of these tools.

Mobility and Diffusion: Moving Computers Beyond the Lab or Classroom

In contrast to the classroom–lab debate illustrated by the first case, a few of the schools visited took a different approach, by privileging the mobility and diffusion of technologies throughout the space of the school, and encouraging flexibility among teachers to allow student access to technology in a wide range of locations. This approach fosters strategies such as the "computer on a cart" that can move between classrooms, the use of libraries and even hallways as alternate learning environments, and rules that allow students to move easily between classrooms and within the school. As with the use of a computer lab and classroom-based computer use, the location of the technology had a significant impact on the kinds of integration and instruction employed (the *direct* influences of computer placement) as well as on what was seen as possible (the *symbolic* influences).

Luther Public School is an inner-city K-5 school that had made the integration of technology a priority over the past five years. Danielle, the school's principal, pointed out during the interview that part of Luther's success in integrating technology had been its determination to "work with whatever we've got." It is largely this philosophy that gave Luther the appearance of a technology-rich school – there appeared to be computers everywhere – although a number of the computers were out-of-date and would most certainly have been discarded by any other institution. Danielle explained that the staff at Luther had decided to organize their technology in such a way that none of their higher-

end machines were used for keyboarding or drill and practice, both of which Danielle saw as the least important uses of technology. Instead, Luther had a collection of refurbished and donated computers (even a few Commodore 64s!) that were designated to be used solely for less demanding types of software and practices.

One of the most interesting things about this approach was that the staff members at Luther had come together collectively not only to discuss the location and uses for the technology, but also to identify distinctions and make decisions about which machines were best used for specific purposes, and then to organize the technology accordingly. The faster machines were not used to run drill and practice software, or keyboarding, which could just as easily be run on a donated 486 or Mac Classic. These slower machines functioned as "computer skill stations" And were placed in groups in the school hallways, while the better machines were located within the classrooms and the computer lab, called the Advanced Technology Centre (ATC).

This approach to diffusing technology throughout the school had significant implications regarding the types of integration and instruction embraced by the teachers at Luther. Staff members, for example, were aware that there was an important difference between technology skills-acquisition and curricular integration. These teachers did not view keyboarding practice or drill-and-practice software as adequate technology implementation, and thus such experiences were not conducted within the instructional space of the classroom but were instead relegated to the independent working environment of the "skill-stations." Computers in the classroom and the ATC had been explicitly located and identified for use in project-based exploration and production. Danielle explained that, according to the school technology plan, every student at Luther was required to complete an "integrated technology project" in each of three school terms.

In addition to this diffuse use of space, exemplified by the distribution of computers at the "skill stations" in the hallways and the ATC, the staff at Luther had also adopted an approach that favoured the mobility of the school's technology. Each grade-level team (made up of three to four teachers) shared a set of four or five computers mounted on transportable rolling desktops. The grade-level teams decided collectively each year how they wanted to share these computers – some teams split them up so that each class had one computer and others kept the set of computers together in one classroom or moved them between rooms. The mobility of the computers allowed the grade-level teams to adjust their location and organization to fit whatever units of study were being undertaken in any given week. While it was somewhat unclear how much this potential mobility was actually used, the teachers at Luther did have the experience of contributing to discussions about how to locate the technology in terms of its direct link to their teaching practices. As such, these teachers were invited to explore both the *direct* and *symbolic* consequences of this more fluid organization of technology.

Luther had one other set of mobile computer systems, which they affectionately named the "benz" and the "caddy." These were two multimedia centers, both with high-end

computers, a scanner, and one projector. They were mobile units that could be signed out by teachers. It seemed that these units were used a great deal and moved around the school constantly. Without this mobility, presumably these higher-end computers would have been located in a lab setting to which the class as a whole would have had to move in order to make use of them. Similarly, without the mobility of the grade team computers, each classroom would probably have had one or two in-class computers, instead of the option to use four or five when needed. This mobility within the school and between classrooms offered greater and more convenient access to a limited amount of high-end computer equipment. These machines could be shared more easily and efficiently by a greater number of teachers while the ethic of mobility helped facilitate a culture among teachers where people learned to ask for and negotiate what they needed.

The choice made by Luther staff, to call their computer lab the Advanced Technology Centre, also indicates a different kind of commitment to the location and use of technology. The Advanced Technology Centre is discursively located in contrast to the everyday practices of keyboarding and computerized assessment as a space for advanced project-based work. Thus, even the discourse at the school seems to reflect and reinforce the kinds of choices that have been made about what kinds of space the technology will take up.

Formal Design: Some Observations on "Space" and the Placement of Computers in a Newly Built Elementary and Secondary School

Schools like Watson and Luther demanded innovation and flexibility in the organization of new technologies given the constraints of older school structures. However, recently built schools have the advantage of incorporating the requirements of computer technologies and philosophies of integration into their design. In this section, the following two schools to be discussed were built in the last five years and are better suited to architecturally and structurally accommodate new technologies. The schools are mentioned here because they serve as examples of how an educational institution might be built to accommodate not only possibilities for new technologies, but also possibilities to re-conceptualize how newer technological tools might be placed within schools to better support teaching and learning.

Green Valley is a relatively new elementary school (5 years old) located in a small rural area in Western Canada. The school was built in consultation with its first administrator and a key consideration in the planning was the placement of computers in the school building. As a result, in both wings of the school there were approximately 10-12 computers, which any student and class could access at any time. These pods of computers were not housed in any classroom, but space had literally been made for them "in the hall," an open space which would otherwise be wasted. There were also pods of computers located in "technology centers" (not "labs"), to which all classes had access. As a result, teachers sent their students to use computers frequently and without direct supervision.

What was interesting about Green Valley was the way in which the principal, vice-principal and the teachers all felt that the architecture of the school and the placement of

computers within it *enabled* them to make better, more appropriate use of computers. Tracy, the vice-principal, described the founding principal who had worked with the architects to build the school as a "visionary". His leaving meant that leadership in the school had undergone significant transition in the previous five years (three principals in five years) but, Tracy insisted that the original "vision" for the school had remained intact, despite these changes. Tracy suggested that the vision had survived various administrative changes because the purposes and uses of technologies in the school were adopted at a "grassroots" level, by students, teachers and administrators. That the computers were "visible" in the school (not hidden away in classrooms and labs) enabled both teachers and students find uses for them as "integrated tools" for learning – not as "add-ons".

One further example of new school architecture that intentionally takes into account the integrated use of technology by teachers is a high school in the Atlantic provinces. Hemlock High School is a modern, open architectural structure with a large gym, a centralized cafeteria, a large-staged auditorium, and classrooms arranged in wings by department (subject area). Each wing, except for the science wing, had classrooms arranged around a lab space with large windows where approximately 20–25 computers are placed around the edges of the room, facing outwards. The computer lab's windows allowed teachers from each classroom to supervise and observe their students as they used computers. Thus, teachers could send just a few students at a time to the lab or they could use the lab with their whole class at once.

The teachers at Hemlock directly influenced how the school would be organized and built. According to one of the district's technology consultants, teachers from the old high school, representing each of the departments, suggested the way that they wanted their department designed, including where they wanted technology to be placed. The teachers agreed that technology should be easy to access, visible, and shared among teachers – to accommodate this the teachers came up with a design where the computers were placed in "studios" or "modules" which four classrooms could share. In the classrooms that had their own computers, they were organized in small clusters of five to eight. This was an unusual arrangement for a high school – most high schools did not have computers in classrooms, but instead placed them in one or two labs which doubled as computer science classrooms. The choices involved in design and organization made Hemlock look a bit more like an elementary school – students worked in small groups on different tasks.

It is noteworthy that both Green Valley and Hemlock have been recognized by a national award program designed to highlight schools that are "innovative" users of new technologies. In visits to these schools, however, what was striking was not so much the actual practices of teachers and students (few of which could be characterized as "innovative"), but the affordances of newly built schools which had considered, "from the ground up" the practical physical arrangement and location of computers within the school. In these schools, as in every one of the 32 schools visited, the teachers spoke about the location and organization of computers as *significantly* contributing to whether and how

they made use of those technologies. In addition, teachers and administrators attributed their ongoing use and educational application of these digital tools to the physical access they and their students had or did not have on a daily basis.

Conclusion

Glass (1997) notes that structurally, spatially and even environmentally, classrooms have changed very little since the late 1800's, although workplaces have changed radically since then (especially those which have had to accommodate computers). In this study, what was striking in conversations with teachers, administrators and technology support staff was how often the location and arrangement of computers not only enabled or disabled use of those machines, but often also re/structured and re/defined in significant ways the kinds of instruction and tasks teachers envisioned with their students. In the case of Watson Elementary, for example, a number of teachers reported that because they were unable to access even a small lab of computers where their students could work in groups on projects, they did not assign as many class projects which required the use of computers. On the other hand, in each of the other three examples, whether the creative restructuring of space for computers at Luther or the newer architectural consideration and support for the machines at Green Valley and Hemlock, the teachers indicated that the ways in which the technology was organized *enabled* what they wanted to accomplish with their students.

In the preceding examples, which draw upon an anecdotal body of data, the importance of considering location and arrangement of computers in relation to possibilities for teaching practices has only been touched upon, and it is certainly the case that this is an area that warrants further exploration and inquiry. Just as classrooms with desks that are fixed in rows can indicate teaching in its most traditional (and some argue) least effective form, so too can the arrangement of computers delimit and signal instructional possibilities for using computers. This is not to argue, however, for more research that examines the placement of computers in schools from an ergonomic design approach, which frequently does not consider financial constraints and instead produces what amounts to a "wish list" of how things might be different. Rather, the argument here is that the "everyday" conceptions and uses of "space" in relation to computers in schools (that is the physical location and placement of these technologies) can reveal more about how those machines are actually being used in teaching and learning than more specialized discourses and practices which consider these spaces in terms of their optimal, ergonomic and environmental design (Fraser, 2002; Glass, 1997; Oates, Evans, & Hedge, 1998; Straker & Pollock, 2003).

The impact of physical organization on instruction is an especially important consideration given the frequent assertion that the introduction of computers into classrooms can be a "catalyst" for change – that is, that teachers' integration of computers into their curriculum and instruction can act as a catalyst for changing teaching practices, transforming more "traditional" teachers into collaborative facilitators for student-centered learning (Sandholtz, et al., 1997). If the practical arrangement of the technology itself does not support collaborative learning, it certainly seems less likely that change could occur in the

ways in which some theorists and researchers so optimistically assert.

In a public lecture "New Media, New Learning", Janet Murray (2001) discussed a project at MIT which illustrates the ways in which, as digital tools make new forms of knowledge and representation possible, pedagogical changes in tandem require new spatial arrangements. She described a physics teacher who began to use computer-generated 3-D models to teach a course which had previously been taught in a large lecture hall, in front of a blackboard, with assessment being gauged by students' production of complex mathematical formulae. This teacher's use of new digital "affordances" for knowledge-representation, led to his replacement of traditional mathematical equations with dynamic graphical modeling. This representational change not only altered what counted as curricular knowledge, it altered in turn, both how the curriculum could be taught and the criteria for assessment of student learning. In addition, to make these transformations possible meant a reorientation of instructional space: the class moved from a lecture hall to a large room in which students sat at tables around laptop computers.

Murray 's example suggests that in making use of these new tools, questions of curriculum, pedagogy, knowledge and space intersect in ways which research has infrequently anticipated or articulated. Deploying new technologies in ways that actually transform curriculum and pedagogy requires an exploration of new spatial 'frontiers' as well. In learning more about how to effect genuinely transformative and not merely additive uses of technologies for education, there is an increasing demand for greater thoughtfulness about the organization of these technologies in the space of the school.

Therefore, instead of looking to newer and more powerful technologies, or better-trained and more "innovative" teachers, or more insistently "transformative" policies for institutional change in education, attention should be turned to the physical spaces in which all of these elements are expected to converge. Innovative ideas for working with computer technologies in the space of the schools will not be found in any esoteric ergonomic design of dizzyingly expensive labs and classrooms few schools can ever hope to afford, but by looking at how—and *where*—teachers and students actually make the best uses out of their tools. Clearly there are needs for remodelling, for re-wiring, and for a host of other expensive structural changes to the physical plant of the school, and these can and must come in time. But there are, as well, spatial arrangements which can be made with little or no cost, many of which can even give back to music and art rooms and libraries the spaces which computers have taken away.

To understand more about the optimal redeployment of institutional space in schools, whose architects could never have envisaged the new demands computer technology places on the physical layout of schools, what is required is a more concerted investigations of the kinds of considerations this research only opportunistically came across when something quite different was being sought: investigations of how the most effective technology-using schools and classrooms quite *literally* "find space" for computers in education.

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References

Bauer, J., & Kenton, J. (2005). Toward technology integration in the schools: Why it isn't happening. *Journal of Technology and Teacher Education*, *13*(4), 519-546.

Beers, M., Paquette, K., & Warren, J. (2000). Student view of classroom technology use.*Society for Information Technology & Teacher Education International Conference: Proceedings of SITE 2000.* (11 th, San Diego, California, February 8-12, 2000).

Bebell, D., Russell, M., & O'Dwyer, L. (2004). Measuring teachers' technology uses: Why multiple-measures are more revealing. *Journal of Research on Technology in Education*,*37*(1) 45-63.

Becker, H. (1984). School uses of microcomputers: Report #5 from a national survey. *The Journal of Computers in Mathematics and Science Teaching*, *41*(1), 38-42.

Becker, H. (1999). *Internet use by teachers: Conditions of professional use and teacher-directed student use.* Irvine, CA: Center for Research on Information Technology and Organizations.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom.* Cambridge, MA: Harvard University Press.

de Castell, S., Bryson, M., & Jenson, J. (2002) Object lessons: Towards an *educational*theory of technology. *First Monday, 7*(1). Online athttp://www.firstmonday.dk/issues/issue7_1/castell/

Dwyer, D., Ringstaff, C., & Sandholtz, J. H. (1990a). *Teacher beliefs and practices. Part II: Support for change. The evolution of teachers' instructional beliefs and practices in high-access-to-technology classrooms. First-fourth year findings.* Cupertino, CA: Apple Classrooms of Tomorrow.

Dwyer, D., Ringstaff, C., & Sandholtz, J. H. (1990b). *Teacher beliefs and practices. Part 1: Patterns of change. The evolution of teachers' instructional beliefs and practices in high-access-to-technology classrooms. First-fourth year findings.* Cupertino, CA: Apple Classrooms of Tomorrow.

Fraser, M. (2002). *Ergonomics for grade school students using laptop computers*. Proceedings of the XVI International Occupational Ergonomics and Safety Conference, Toronto, Canada, June 10-12, 2002

Fulton, K., & Sibley, R. (2003). Barriers to equity. In G. Solomon, N. J. Allen, & P. Resta (Eds.), *Toward digital equity* (pp. 14-24). New York: Allyn and Bacon.

Gayeski, D. M. (1995). *Designing communication and learning environments.* Englewood Cliffs, NJ: Educational Technology Publications.

Glass, T. (1997). Schools built for technology: The effects of technology on educational facilities. *School Business Affairs*. *63*(2), 11-17.

Goldberg, A., Russell, M., & Cook, A. (2003). The effect of computers on student writing: A meta-analysis of studies from 1992 to 2002. *Journal of Technology, Learning and Assessment, 2*(1). Retrieved September 1, 2005, fromhttp://www.bc.edu/research/intasc/jtla/journal/v2n1.shtml

Green, E. E., Cook, P. F., & Bolt, L. (1996). Fitting new technologies into traditional classrooms: Two case studies in the design of improved learning facilities. *Educational Technology*, *36*(4), 27-38.

Hernandez-Ramos, P. (2005). If not here, where? Understanding teachers' use of technology in Silicon Valley schools. *Journal of Research on Technology in Education*, *38*(1), 40-64.

Murray, J. (2001). "New media, new learning." Public Lecture. Vancouver, British Columbia. November 11, 2001.

Najmi, J. (1996). Instructional labs: Pluses and minuses. *Proceedings of the mid-South instructional technology conference*. (1 st, Murfreesboro, Tennessee, March 31-April 2, 1996).

Norris, C., Sullivan, T., Poirot, J., & Soloway, E. (2003). No access, no use, no impact: Snapshot surveys of educational technology in K-12. *Journal of Research on Technology in Education*, *36*(1), 15-27.

Oates, S., Evans, G., & Hedge, A. (1998). An anthropometric and postural risk assessment of children's school computer work environments. *Computers in the Schools*, *14*, 55-63.

Ravitz, J., Wong, Y., & Becker, H. (1998). *Teaching, learning and computing: A national survey of schools and teachers describing their best practices, teaching philosophies, and uses of technology.* Irvine, CA: Center for Research on Information Technology and Organizations.

Ravitz, J., Wong, Y., & Becker, H. (2000). *Constructivist-compatible practices among US teachers.* Irvine, CA: Center for Research on Information Technology and Organizations.

Sandholtz, J. H., & Reilly, B. (2004). Teachers, not technicians: Rethinking technical expectations for teachers. *Teachers College Record106*(3), 487-512.

Sandholtz, J. H. Ringstaff, C., & Dwyer, D. (1997). *Teaching with technology: Creating student-centered classrooms*. New York: Teachers College Press.

Sharples, M. (2000). The design of personal mobile technologies for lifelong learning.*Computers and Education*, *34*, 177-93.

Shamburg, C. (2004). Conditions that inhibit the integration of technology for urban early childhood teachers. *Information Technology in Childhood Education Annual*, 227-244.

Silvernail, D. L., & Lane, D. M. M. (2004). *The impact of Maine's one-to-one laptop program on middle school teachers and students. Phase one summary evidence. Research report #1.*Gorham, ME: Maine Education Policy Research Institute, University of Southern Maine Office.

Smerdon, B., Cronen, S., Lanahan, L., Anderson, J., Iannotti, N., & Angeles, J. (2000). Teachers' tools for the 21 st century: A report on teachers' use of technology. Statistical analysis report. *National Center for Education Statistics (NCES)*. Washington, DC.

Straker, L., & Pollock, C. (2003). Delivering the power of computers to children, without harming their health. *Proceedings of the XVth Triennial Congress of the International Ergonomics Association* , Aug 24-29, 2003, Seoul, Korea

Swan, K., van 't Hooft, M., Kratcoski, A., & Unger, D. (2005). Uses and effects of mobile computing devices in K-8 classrooms. *Journal of Research on Technology in Education*,*38*(1), 99-112.

Weinstein, C. S. (1981). Classroom design as an external condition for learning. *Educational Technology*, *21*(8), 12-19.

Wilson, G. (1993). *Evaluating the impact of technology at Peakview elementary school: The full report.* ERIC.

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