# A STUDY ON THE EFFICACY OF A THIN CLIENT SCHOOL TECHNOLOGY INFRASTRUCTURE

*FINAL REPORT*

CENTER FOR CHILDREN & TECHNOLOGY

CCT REPORTS
JULY 2003

# A STUDY ON THE EFFICACY OF A THIN CLIENT SCHOOL TECHNOLOGY INFRASTRUCTURE

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FUNDED BY CLASSLINK TECHNOLOGIES

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This report was written and produced by EDC's Center for Children and Technology

*Introduction*

As computers, the Internet and other digital technologies become integral to educational settings, educators and policy makers need to understand the complex relationship between technology infrastructure and the learning environment it supports. The information that flows through and resides in this technology backbone impacts all aspects of a school from teaching to learning to administration.

This report presents findings from the EDC Center for Children and Technology's evaluation of a thin client networking system developed by ClassLink Technologies for use in schools. In this study, we examined the impact ClassLink's thin client infrastructure has on network administration, on the management of student work products and practices, on communication patterns within the school community, and on technology budgeting issues. For our investigation, we selected Union City, New Jersey, an urban, Northeastern district, where ClassLink has been working for the last three years. Union City is a national leader both in terms of systemic educational improvement and large-scale technology integration (Honey, Hawkins et al. 1998; EDC Center for Children and Technology 2000). Three middle schools volunteered to participate in the study. One school has been using ClassLink's thin client networking solution for three years. The other two have local area netowrks (LANs) not based on thin client technology. We designed a research program of interviews, observations and surveys to build a broader picture of the relationship between technology infrastructure and the learning environment. By looking at three schools in the same district with comparable student and teacher populations, a common curriculum, and a common approach to technology, we are able to make robust observations about the particular affordances and liabilities of ClassLink's thin client infrastructure.

## The thin client network

Understanding the basic differences between thin client networks and typical local-area or wide-area networks (LANs and WANs) is necessary to investigating the different affordances that each system may have for educational settings.

Currently, most school computer networks are comprised of many individual computers. All computer processing occurs on the individual computer, powered by the computer's central processing unit (CPU) and using software stored on the computer's hard drive. In a LAN, these individual machines are linked together in a network that connects them to the Internet and to central servers where files can be centrally stored, typically at the discretion of the individual user. The most important part of the system is the individual computer.

With a thin client network, all of the computing power resides on the central server (or servers), not the individual computer. Individual workstations act as remote terminals for these powerful central computers. Because the actual processing and storing of software and files occurs only on the server, the workstations are not dependent on the CPU or the memory capacity of individual computers; instead they need only provide the basic ability to receive input, transmit it to the server, and display the results. These workstations can therefore be simpler (or "thinner") than full-capacity computers. Rather than employing full-capacity computers, a thin client network can make use of specialized devices (referred to herein as "thin clients", or "thin client terminals") that are both simpler and less expensive than full-capacity computers, and rely on the server for access to applications and other services. Full-capacity computers can also be set up to run as thin client terminals (or "workstations") and the user can switch between using it as a workstation or as an individual computer. Older and less powerful computers can thus be used as functional thin client workstations. In this infrastructure the server is the key part, so almost all hardware maintenance, software installations, memory or hardware upgrades occur on the server.

# Methodology

## *Research Design*

In preparing to evaluate the ClassLink infrastructure's effectiveness in supporting educational technology in Union City, we needed to develop a list of key functional attributes of any school infrastructure. These functional attributes would help us evaluate our four broad research questions. We reviewed relevant literature to inform our development of research questions and evaluation criteria that would help us appraise ClassLink's responsiveness to the most important needs and challenges that education technology (ed-tech) infrastructures must address. There is a reasonable consensus in the ed-tech community around the vital attributes of an effective technology infrastructure. The literature on educational technology offers a number of analytical frameworks for school technology, but for ease of use we adopted the model of high technology performance developed by the North Central Regional Education Laboratory (NCREL) (Jones et al, 1995). NCREL's framework offers a clear and concise articulation of key factors that also appeared – in slightly varying form – in a wide range of publications by researchers from the government (National Center for Supercomputing Applications, 1996; NCRTEC, 1995; November & Staudt, 1998), commercial (International Data Corporation, 1997; Picus, 1997), non-profit (Consortium for School Networking, 2001) and education (NSBA, 2002) sectors. Table 1 (see page 4) lists the six dimensions of high technology performance and defines the general indicators of each dimension. The broad definitions of functional attributes are as follows:

- A school's technology infrastructure should offer easy and widely distributed access points. The computing infrastructure should be internally networked and connected to the Internet.
- Operability refers to the extent to which the infrastructure's architecture is open to sharing data across programs, to supporting diverse software and to interfacing with peripherals and external devices.
- The organization of a high performing educational technology infrastructure should distribute resources, allowing users entry to the system when and where they need access. The organization of the infrastructure should also facilitate user collaboration.

- Engagability is the extent to which the technology infrastructure supports teachers and students in engaging in challenging, deep learning activities. The human infrastructure and the capacity of the technology coordinators play a central role here.
- Ease of Use describes the technology's simplicity, speed, reliability and the availability of support when needed.
- Functionality describes the system's ability to provide access to the fullest range of technology tools and skill building opportunities.

**TABLE 1: FUNCTIONAL ATTRIBUTES OF HIGH TECHNOLOGY PERFORMANCE.**

| **Dimension** | **Indicator of High Technology Performance** | **Indicator definition** |
|---|---|---|
| Access | Connective | Schools are connected to Internet and other resources |
| | Ubiquitous | Technology resources and equipment are pervasive and conveniently located for individual (as opposed to centralized) use |
| | Interconnective | Students and teachers interact by communicating and collaborating in diverse ways |
| | Equity | All students have access to rich, challenging learning opportunities and interactive, generative instruction |
| Operability | Interoperable | Capable of exchanging data easily among diverse formats and technologies |
| | Open Architecture | Allows users to access third-party hardware/software |
| | Transparent | Users are not — and do not need to be — aware of how the hardware/software operates |
| Organization | Distributed | Technology/system resources are not centralized, but exist across any number of people, environments, and situations |
| | Designed for user conditions | Users can provide input/resources to the technology/system on demand |
| | Designed for Collaborative Projects | Technology is designed to facilitate communication among users with diverse systems/equipment |
| Engagement | Access to challenging tools | Technology offers or allows access to tasks, data, and learning opportunities that stimulate thought and inquiry |
| | Enables learning by doing | Technology offers access to simulations, goals-bas edlearning, and real-world problems |
| | Provides guided participation | Technology responds intelligently to user and is able to diagnose and prescribe new learning |
| Ease of Use | Effective help | Technology provides help indices that are more than glossaries; may provide procedures for tasks and routines |
| | Use friendly/user controlled | Technology facilitates user and is free from overly complex procedures; user can easily access data and tools on demand |
| | Fast | Technology has a fast processing speed and is not "down" for long periods of time |
| | Available training and support | Training is readily and conveniently available, as is ongoing support |
| | Provides just enough information, just in time | Technology allows for random access, multiple points of entry, and different levels and types of information |
| Functionality | Diverse tools | Technology enables access to full diversity of generic and context-specific tools basic to learning and working in the 21st century |
| | Promotes Programming | Technology provides tools (e.g., "wizards") that are used to make other tools |
| | Media Use | Technology provides opportunities to use media technologies |
| | Supports project design skills | Technology facilitates the development of skills related to project design and implementation |

(from Jones et al, 1995)

# RESEARCH QUESTIONS

To develop our research questions, we reinterpreted the above attributes into categories that reflect the way schools actually deal with their technology infrastructure. We hypothesized that ClassLink would impact four major areas of interest to educators and education policy audiences: network management, work practices, communication patterns and budgeting, all of which are crucial challenges for successful technology integration. In each one of these four areas we developed focused questions to guide our research. Our four guiding questions intersect at multiple points with the six dimensions of high technology performance outlined in the NCREL framework.

- ***Network Management: Does ClassLink reduce infrastructure barriers to technology use?*** We investigated ClassLink's effectiveness as an infrastructure solution. In particular, we looked at the impact of ClassLink on school personnel's[1] perceptions of the reliability of the network, and on distribution of and access to computing resources. Further, we looked for evidence of ClassLink's effect on teachers' classrooms and their daily activities. These questions intersect primarily with the NCREL-defined dimensions of access (see the ubiquitous indicator), operability (see the open architecture and transparent indicators), organization (see the distributed indicator), engagability (see the access to challenging tasks indicator) and ease of use (see the available training and support and fast indicators).

- ***Work Practices: Does ClassLink facilitate and support students and teachers in the technology practices central to a school's learning environment?*** We examined both teacher and student use of technology through surveys and interviews. Teacher and student questions included process items such as saving, retrieving files, keeping track of revisions and protecting files. These questions intersect with the NCREL-defined attributes of access (see the interconnective and ubiquitous indicators), operability (see the interoperable indicator) and organization (see the designed for collaborative projects indicator).

- ***Communication Patterns: What is the relationship between ClassLink and communication within the school community?*** We looked for evidence of the impact that ClassLink's internal email system had on teacher-teacher, student-student, teacher-student, and home-school communication patterns. These questions intersect primarily with the NCREL-defined attributes of access (see the connective, ubiquitous, and interconnective indicators), operability (see the interoperable indicator) and organization (see the distributed and designed for collaborative projects indicators).

- ***Budgeting: What impact does adoption of ClassLink's thin client infrastructure have on technology budgeting?*** Budgeting is an essential issue for all schools, but not directly addressed by NCREL framework. We looked for indications of effects on areas such as maintenance, hardware obsolescence and replacement, and technical support costs. This question intersects with principles of "Total Cost of Ownership" (TCO). TCO, a concept borrowed from the business world, consists of all costs incurred during the life cycle of an asset, including pur-

[1] technology coordinators, teachers and media specialists

chase, deployment, operation, support, and disposal. Recent thinking within the ed-tech community has proposed that, by identifying and quantifying all the costs of technology, long- and short-term, obvious and hidden, administrators can do a better job of reducing those costs by anticipating needed investments before they become expensive crisis-management (COSN, 2001).

## Data Collection

The research was conducted in three stages. During the first phase, the research team interviewed teachers and administrators to build a description of the technology infrastructures in each school and to generate a list of key factors that would inform the composition of the surveys. The focus of this phase was on detailing how the different environments impact teachers' and students' use of technology, and decisions about resource allocation. The second phase of the research was a pair of surveys for teachers and students developed from the information collected in phase one. The third phase of the research was an interview process with administrators, teachers and students deepening our understanding of the issues identified and examined in the first two stages of the project.

The surveys illuminated the school-wide impact of technology infrastructure and allowed us to identify consistent differences between the ClassLink environment and the other environments. The surveys were conducted online. For the teacher survey, all classroom teachers in each building were sent an email announcing the survey and inviting their participation. To support the survey endeavor, the Board of Education raffled off two laptops to the participating teachers. The teacher survey had a response rate of 47% overall, ranging from 33% at the LAN1 school to 58% for the thin client school. The student survey was conducted among the sixth grades in each building during their technology class. The sixth grade was selected because the students are old enough to easily understand and respond to a survey. We surveyed the students in their technology classes because all sixth graders take this class and they have easy Internet access during the class. The student response rate was 72% for all three schools. The surveys (of teachers and students) contained items about technology use (frequency, type of programs, etc.), learning activities, and work places (class, after- school, home other), barriers to technology use (downtime, lack of support, lack of computers) and communication patterns (emailing teachers, showing work to parents or peers, etc.).

| **TABLE 2: SURVEY RESPONSE RATE FOR TEACHERS AND STUDENTS** | | | |
|---|---|---|---|
| **Teachers** | Total number of teachers | Number of respondents | Response rate (%) |
| Thin client | 130 | 75 | 58% |
| LAN1 | 115 | 38 | 33% |
| LAN2 | 90 | 45 | 50% |
| Thin Client | 180 | 134 | 74% |
| LAN1 | 150 | 103 | 69% |
| LAN2 | 124 | 91 | 73% |

# The Context of Union City

## *Demographics*

Although Union City receives compensatory funds for education from the state, it has been classified as one of the most impoverished communities in the United States: currently 28% of all children live below the poverty line and 84% receive free or reduced-price lunches. Of the approximately 11,000 students in this eleven-school district, 93% are Latino, representing a variety of Spanish-speaking nations.

While the district does not collect aggregate data on the country of origin for immigrant students and families, a CCT research survey (2001) conducted at a Union City High School provides a detailed demographic snapshot of the class of 2002. Of the 95% of students who identify themselves as Latino, 47% were born in the U.S. while 50% were born in Latin America (with 3% born elsewhere). The largest groups of non-U.S. born students are from the Dominican Republic (16%), followed by Ecuador (9%), Colombia (6%), Cuba and Peru (4% each), Puerto Rico (3%), and Honduras, Mexico, El Salvador, Nicaragua, and Venezuela (under 2% each).

Within the entire Union City K-12 student body, 69% of students do not speak English at home and 14% have been in this country for less than three years. More than one-third of the district's faculty teaches in bilingual/ESL programs.

## *Union City Schools: Technology Context*

For more than a decade, Union City has used technology as a cornerstone of a comprehensive educational reform effort in its school system. This effort includes a strong, communicable core-learning philosophy, leadership at the building and district level, professional development, an emphasis on students' expressing ideas in multiple, creative formats, and multi-text approaches to learning that stress documentation, synthesis, and evaluation (Honey, Culp, & Carrigg, 2000). These comprehensive systemic improvement efforts in the Union City school district have had demonstrable impact upon the elementary, middle and high schools. In 1989 the Union City School District showed deficiencies in 44 of the 52 areas of proficiency the state investigated. By 1995

Union City's scores on the state's eighth-grade readiness test were superior to those of its urban counterparts by as much as 20 percentage points. This level of success continues today. In the words of the district's executive director of academic programs, "The technology is not an end in itself but a means to an end. Technology supports our learning philosophies." Specifically, technology supports four underlying pedagogical objectives:

- Providing access to information that was generally denied to the inner-city poor because of the paucity of community resources;
- Developing literacy to enable students to document, synthesize and evaluate information;
- Promoting students' ability to communicate ideas to others; and
- Facilitating cooperative learning.

Educational technologies have offered the district some unique opportunities to pursue these basic objectives: networking technologies offer schools access to unprecedented amounts of information, and students and teachers can communicate with peers and colleagues in ways that would be impossible without these technologies; multimedia technologies allow students to express more complex ideas in more sophisticated ways (Thompson Keane, Kim & Gersick, 2002). Technology also plays a key role in school and district management, planning, administration, and school-family communication. District leaders cite the early decision to network (interconnect) the multiple groups that constitute the school system - the students, teachers, school and district administrators, and parents – as fundamental to the district's success. Email and web-based applications have been a great help facilitating communication between these different groups.

Against this background of high - and highly integrated - use of technology, each of the schools we studied has built a different infrastructure within their respective school buildings. The following section provides a brief overview of each school and its infrastructure.

## *The thin client school.*

The thin client school has an enrollment of 1,612 students in grades pre-K – 8, making it one of the largest schools in the state: 34% are Limited English Proficient (LEP) and 63% speak Spanish as a first language at home. Lastly, 82% of students qualify for federal free or reduced-price lunch programs.

The thin client school's server-based infrastructure is designed with an emphasis on expanding accessibility to the network beyond classroom or school boundaries, and on consolidating resources on a central server. The mechanics of the school's ClassLink thin client network are discussed above (see pp. 1-2). Through a password-accessible account, students, teachers, and administrators can store and access saved documents, personal settings, and a ClassLink email account on the server. Because all files and programs are stored centrally, users can access their work from any computer on the network or from any Internet-ready computer (at home, the library, etc.). All the printers in the building are connected to the network and, with appropriate authorization, accessible from any terminal in the building. In addition to its thin clients, the thin client school has many full-capacity computers. While most of these have been converted to thin client terminals, they can also be taken off the network and used as individual, fully capable computers. There is also a wireless component to the ClassLink network. The school maintains two class sets of wirelessly networked laptops, which are shared by students in four homerooms. Students can run a thin client session on the laptop or use it as an individual computer.

**TABLE 3: COMPUTER INVENTORY IN EACH BUILDING.**

| School | Instructional Computers | Administrative Computers | Total Computers |
|---|---|---|---|
| Thin client | 539 | 33 | 572 |
| LAN 1 | 413 | 24 | 437 |
| LAN 2 | 275 | 25 | 300 |

### The LAN1 school.

The LAN1 is a pre-K-8 school with 1,245 students enrolled: 38% are Limited English Proficient (LEP); 74% speak Spanish as a first language at home; and 95% of students qualify for federal free or reduced-price lunch programs.

The LAN1 school, which has a typical school LAN model with no wireless component, has developed an extensive infrastructure over many years and thus has multiple generations of computer systems with diverse capabilities as well as multiple versions of software programs. Each individual computer maintains its own software programs, and, while students and teachers can save their work to network-based folders on a server, these folders are not accessible building-wide.

### *The LAN2 school.*

The LAN2 school has an enrollment of 1,090 students in pre-K through 8th grades. Forty-four percent are Limited English Proficient (LEP) and 76% speak Spanish as a first language at home. Seventy-seven percent of students qualify for federal free or reduced-price lunch programs.

The school has made a push towards mobile computing and their infrastructure combines desktop computers and a large number of laptops (108). All of the school's computers are networked. The wireless mobile laptops are shared across multiple classrooms allowing teachers to bring in 10 to 20 additional machines when needed. These laptops connect to the network through a wireless networking system. All computers and printers in the building connect to the same network and can access the central servers. Software is run from individual machines, but students and staff save their work to a folder on the network that is accessible from anywhere in the building.

# Findings

We grouped the findings from this study according to four areas of investigation – network management, work practices, communication patterns and budgeting.

## *Network management*

Network management is at the core of the challenges schools face in maintaining a learning environment that depends on a healthy, flexible technology infrastructure and encompasses elements that relate to multiple dimensions of our framework for technology performance. We found that ClassLink's thin client infrastructure has positive implications for technology staff's ability to offer troubleshooting and technical support, for the stability and reliability of the network, and for the flexibility of the ClassLink school's infrastructure.

### Technology Coordinators' Multiple Roles: Troubleshooting, Upgrading and Pedagogical Assistance

In interviews, we asked school technology coordinators and the district's director of technology about their current distribution of time and resources across the three areas of responsibility described above – setup and maintenance, troubleshooting, and promoting effective integration. The technology coordinators described their typical workdays and identified how they and their staff distribute time across activities. We surveyed teachers in each building about their satisfaction with the technical support provided in each school. From these investigations, we derived a picture of how the thin client architecture impacted the technology support staff's efforts to fulfill all of their responsibilities.

School technology coordinators and support staff mediate between the infrastructure and the technology users in the school. In facilitating functional technology use, the technology-support staff handles multiple tasks – setting up and maintaining infrastructure, troubleshooting, and promoting effective integration of technology into teaching and learning. In high-use schools such as those we examined in this study, tech-support staff can become stretched thin as they are called upon to design and implement school technology plans, troubleshoot ongoing problems and provide planning and professional development to help teachers integrate technology into the curriculum. One technology coordinator described her work as a complex juggling act with multiple responsibilities and constituents:

> *A typical day? What I do now is I run a lot of programs […] I'm coordinating the Extended Day Program and staff development. This morning I'm getting all the teachers their folders and class lists. I'm also trying to promote integration so I have a contest for who's doing the most technology integration. I'm planning a voluntary lunchtime training - last Monday I trained teachers to use our [technical problem logging software] and how to utilize their E-portfolios. I also maintain the software. Any new software that comes in, unpacking it – I'll stay after school to do installs. Just maintaining the software servers! I am also in the middle of Fall Report – every single administrator has to be able to access it – and it's due [soon]*

*and we switched over to a different database so I have to go around and make sure everyone has Explorer 5.0 on their machines. I like to stay after school – you get interrupted constantly during the day by people who have questions or technical problems. So I like to stay after school if I want to do something that requires me to concentrate for more than fifteen minutes. (Technology coordinator interview)*

In this type of scenario, technology coordinators and staff with multiple responsibilities are left with little time for the more long-term, process-oriented tasks of helping teachers design or refine technology-related curriculum. The need to upgrade software, operating systems and hardware can take up much of a technology coordinator's available time. Cross-platform, cross-operating-system compatibility issues complicate the task of upgrading. At the same time, because the need for troubleshooting is both continuous and requires immediate resolution, demands in this area often take precedence can trump other responsibilities. In this district, overflowing time demands can undermine a technology coordinators' ability to fulfill the purpose for which they were originally hired:

*Technology coordinators were originally hired to help integrate the technology into the curriculum. However, they wound up doing nothing but repairing hardware, downloading, installing and updating software, and maintaining the tech-side aspect of the school. Even schools with student teen tech programs are not able to take full advantage of their tech coordinators. (Executive Director of Academic Programming for the District)*

**What is the impact of a thin client infrastructure on technology staff's workload?**

Troubleshooting and upkeep responsibilities can usurp the majority of technology staff's time. This is the case at the LAN1 school, where the technology coordinator reported spending the majority of her time on these tasks, with a backlog of requests that creates a week's delay for "most repairs." This technology coordinator must manage the backlog of troubleshooting tasks while simultaneously attending to her other goals for the year, such as offering professional development trainings for low-using teachers, and installing new instructional software packages on the individual hard drives of each computer in the building.

Technology coordinators at the other two schools report that they spend less time on troubleshooting and maintenance. Data provided by the district's centralized maintenance log on the number of reports submitted since the fall of 2002 through January of 2003 indicate a substantial difference between the three environments. ClassLink environment had 168 reports among 572 computers, making it the most trouble-free environment at 29 complaints per 100 computers. The LAN1 school, which also has a substantial number of older machines, had 309 reports among 437 computers or a ratio of 71 per 100 computers.

**TABLE 4: NUMBER OF TECHNICAL REPORTS FILED BY USERS IN EACH BUILDING PER 100 COMPUTERS.**

| School | Reports | Computers (includes instructional and administrative) | Reports per 100 computers |
|---|---|---|---|
| Thin client | 168 | 572 | 29/100 |
| LAN 1 | 309 | 437 | 71/100 |
| LAN 2 | 109 | 300 | 36/100 |

In the thin client school, the technology coordinator reported that her centralized network frees her from devoting her time to troubleshooting and routine maintenance: "Because of thin client I'm able to do my administrative [work]. I [also] do a lot of development work here because thin client has freed me to do that."

The amount of time needed to address technical problems and to provide basic support is also reflected in the differences in teachers' responses on the survey about the reliability and stability of the network (discussed later in this report).

**What is the impact of the thin client environment upon network administration tasks?**

Technology coordinators need to continuously improve both the engagability[2] and functionality[3] of the infrastructure by providing increasingly effective software and new and diverse tools through upgrading of software and hardware. Network administration also includes keeping track of software licenses. Routine maintenance is crucial to supporting a system's ease of use.

In computer-focused environments where programs run off the hard drive software installation and upgrading must be done on each individual machine, which requires both time and organization:

> *We have an electronic portfolio server which we're trying to move over to OS10 and we have a new software server and 34 packets of new software that will be installed on client stations – that's [a] big task this year, to integrate this software into the classroom. (Technology coordinator, LAN1 school)*

Updating and shifting hardware is another complex operation in overcrowded schools that lack secure and available spaces to store machines.

> *I have 52 machines upstairs waiting to be unboxed, programmed and put on the floor. Prior, 8 new printers went out to rooms that had printers, to upper grades where they are heavily used, and those 8 printers become 16 moves. There's constant movement (of machines) in this building – the older machines go down to lower grades where the student usage isn't as heavy. When something is completely over the hill it goes to a room, gets coded for obsolescence, which goes to the central office. (Technology coordinator, LAN1 school building)*

[2] Particularly in regards to NCREL's "Access to challenging tasks" indicator, which suggests that a high performing infrastructure will "offer…tasks, data and learning opportunities that stimulate thought and inquiry."

[3] Particularly in regards to NCREL's "Diverse tools" indicator, which suggests that a high performing infrastructure will "enable access to a full diversity of generic and context-specific tools basic to learning and working in the 21st century."

The client-server architecture of the thin client infrastructure consolidates the process of software upgrades. According to the thin client school technology coordinator, if we do any software installs, for example, thin client does it on the server."

Thin client networking also centralizes the process of inventorying and licensing software. The technology coordinator in the thin client building reports that "the licensing is the same [as installing software]: I don't have to do it. One license per software for the whole school."

The technology coordinator using ClassLink feels that her centralized network frees her from the need to devote her time to troubleshooting and routine maintenance, allowing her to concentrate on other priorities:

> *I [also] do a lot of development work here because thin client has freed me to do that. We developed a web-based electronic portfolio. We put existing lesson plans on line or [teachers] can create new plans and make them public or private. They can use existing rubrics or create their own. If the project they're doing is something they picked from the board, it will automatically display the core curriculum standards that they're meeting. They create an Inbox concept for the students, decide who it's for, when it's due, the students see the lesson plan and what they have to do. They can monitor who's submitted. Once it's submitted it goes into the working portfolio and the dialogue goes on between teacher and student.*

**What is the impact of thin client infrastructure on the use and management of peripherals?**

District officials initially had concerns about the operability and openness of the thin client architecture. Because the thin client architecture uses terminals running software off of the server, the terminals input keystrokes and receive data back. District administrators we spoke with were initially concerned that the lack of computers in many of the thin client school's classrooms would complicate the use of peripheral devices such as scanners, digital cameras and handheld computing devices (PDA's). According to one of the district administrators "a draw back is that [ClassLink] doesn't support multimedia as well – it doesn't support the ability to do voice recording and thin client also has difficulty with peripherals." In response to the district and school's concerns, ClassLink designed scanner bays for each of the classrooms that allow students to scan material directly into their folders on the server, and the administrators report that the scanner bays "work well."

The teachers were surveyed about two peripherals – scanners and digital cameras. The ClassLink scanner bays appear to be effective, since teachers in the ClassLink environment report a higher use of scanners than the other teachers – 30% sometimes or often use scanners compared to 8% and 19% in LAN1 and LAN2 schools. The results on the digital camera item are more ambiguous. With 30% of the teachers reporting digital camera use, the thin client school falls in the middle between 15% at the LAN1 school and 51% percent at the LAN2 school.

| TABLE 5: USE OF PERIPHERALS. | | |
|---|---|---|
| | How often do you use a scanner with your students? (Percent responding sometimes or often) | How often do you use a digital camera with your students? (Percent responding sometimes or often) |
| Thin client (n=75) | 30% | 30% |
| LAN 1 (n=38) | 8% | 15% |
| LAN 2 (n=45) | 19% | 51% |

However, peripherals for which specific solutions have not been designed remain incompatible with a unilateral ClassLink infrastructure – this is one reason why network administrators retain groups of full-capacity computers to have an infrastructure that fulfills NCREL's definition of high performing "Functionality" as, in part, "enabl[ing] access to a full diversity of generic and context-specific tools basic to learning and working in the 21st century." As an example, the technology coordinator at the thin client school reported that her need to provide access to diverse tools for younger students prohibits her from relying solely on thin client terminals: "The little guys get IMacs –buying thin client terminals is cheaper but I need … the port for headphones, and I need the one-button mouse."

**What is the impact of thin client infrastructure on the problem of hardware obsolescence?**

Aging machines also create a problem for system functionality. Lower performing machines may not meet the school's needs because they cannot run newer software or handle the workload. As one technology coordinator points out, one solution is to move machines down to lower grades which may place less complex demands on certain hardware.

In the thin client school, the technology coordinator does not have to upgrade hardware in the classroom as often since the software is run off of the server. Only the server needs to be capable of running the new software. The coordinator in the thin client school feels that "in the long term, it's cheaper because you don't have to keep buying hardware, you don't replace them unless they break."

**Are teachers satisfied with technical support?**

The drop in demands for technical support reported by technology coordinator in the thin client school does not appear to affect the quality of technical support that teachers receive. One hundred percent of teachers in the thin client school rated the effectiveness of technical support as "good" or "excellent"; 91% rated the timeliness of technical support as "good" or excellent." These numbers are comparable to responses in the other two subject schools (see Table 6); what is notable, however, is that teachers in the thin client school reported these high levels of satisfaction while the technology coordinator reported spending less time on technical support than she did before the thin client model was implemented. At the thin client school, thin client infrastructure allows the technology support staff to supply timely and effective technical support in less time.

| TABLE 6: HOW EFFECTIVE AND TIMELY IS THE TECHNICAL SUPPORT? | | |
|---|---|---|
| | Timeliness (percent responding good to excellent) | Effectiveness (percent responding good to excellent) |
| Thin client (n=75) | 91 | 100 |
| LAN 1 (n=38) | 92 | 97 |
| LAN 2 (n=45) | 93 | 96 |

Students were asked a related question about technical support: How frequently did they feel that their classroom computers were broken? A very small percentage of students (2%) in the school using ClassLink felt that their computers were frequently broken. The student responses in the other buildings ranged from 14% to 32%.

| TABLE 7 STUDENT PERCEPTIONS OF HARDWARE PROBLEMS | |
|---|---|
| | How often are the computers in your classroom broken? (percent responding often) |
| Thin client (n=134) | 2% |
| LAN 1 (n=103) | 14% |
| LAN 2 (n-91) | 32% |

**What is the impact of Thin Client upon infrastructure and network-related problems?**

We asked the teachers to rate the system's stability in four common network-trouble areas – access to the Internet, logging on to the server, speed of access to the server, and ease of printing. Each of these areas impacts teachers' work with students: loss of access to the Internet can derail a research-based classroom activity; slow or blocked access to the server can bring class work to a halt by preventing students from calling up work in progress or saving work, or keeping teachers from downloading necessary software; finally, it is important for students and teachers to be able to see finished products on paper, and printing is a major concern for teachers. Furthermore, to fit within the time constraints of a school schedule, all of these activities have to happen quickly and easily.

Teachers in the ClassLink environment perceived fewer problems with their system on three of four items. The survey results indicate the ClassLink environment has noticeably eased concerns around Internet access, logging on and server speeds. Fewer teachers (6%) in the thin client school report the Internet "often" being down, compared to 20% and 22% in the other schools. Fewer teachers (6%) in the thin client school report often having trouble logging on to the server, compared to 14% and 26% in the other schools (See Table 8). Also, fewer teachers (10%) in the ClassLink environment feel the server is "often" slow compared to 17% and 33% in the other environments. However, more teachers (10%) in the thin client building reported frequent printing problems compared to a low of 5% in the LAN1 school (see Table 8).

**TABLE 8: TEACHER PERCEPTIONS OF NETWORK TROUBLE AREAS.**

| | How frequently is the Internet down? (percent responding often) | How often is access to the server is slow? (percent responding often) | How often do students report problems logging on to server? (percent respond-ing often) | How often do you experience trouble printing? (percent responding often) |
|---|---|---|---|---|
| Thin client (n=75) | 6% | 10% | 6% | 10% |
| LAN 1 (n=39) | 22% | 17% | 14% | 5% |
| LAN 2 (n=45) | 20% | 33% | 26% | 16% |

Students' experience of network and hardware problems parallels the teachers' perceptions. The students in the thin client environment are less likely to report experiencing frequent problems with the Internet being down or having difficulty with the server. No students (0%) in the ClassLink school felt that the Internet was frequently down and in the other two schools, roughly equal percentages of students (11-12%) felt the Internet was frequently down. Few students in the ClassLink environment indicated frequent problems with the server, slow access (5%) and log-on problems (2%), respectively. The semi-wireless LAN 2 had similar ratings on the speed of the server, only 8% felt slowness was a frequent problem, but 49% of the students felt they frequently had problems logging on. However, the LAN2 school had just changed operating systems (to OS10) and student difficulties logging on may be related to confusion over the new system.

**TABLE 9: STUDENT PERCEPTION OF NETWORK TROUBLE AREAS.**

| | How frequently is the Internet down? (percent responding often) | How often is access to the server is slow? (percent responding often) | How often do you have problems logging on to server? (percent responding often) |
|---|---|---|---|
| Thin client (n=134) | 0% | 5% | 2% |
| LAN 1 (n=103) | 12% | 30% | 26% |
| LAN 2 (n=91) | 11% | 8% | 49% |

**How does thin client address issues of ubiquity?**

A pivotal concern in the construction of any computer network is the issue of ubiquitous access, whereby "technology resources and equipment are pervasive and conveniently located for individual (as opposed to centralized) use" (NCREL, 1995). All three of the networks we studied, when functioning properly, provide students and teachers with ubiquitous access to centrally saved work on the server. Thus in both the thin client and LAN2 schools, where the networks were fully functioning at the time of our study, teachers made similar observations about the flexibility of distributed computing in their school building. In both schools, universal access to the server allowed teachers to take advantage of more computers and printers than they had in their classrooms because they could send students to work in other locations.

At the thin client school, one teacher we spoke to made these characteristic comments on the advantages of centralized computing: “ClassLink does make it easier – I can put [an activity template] in the shared folder and the kids can pull it out … It really does enable the kids because they can go and do [their work] in any room.”

Although all three schools offer centralized access to saved work throughout the school building, ClassLink’s thin client network provides the most comprehensive and reliable access – servers are accessible from points beyond the school building, and those accessing the network from outside the school have full access not only to saved documents but also to all software in the system as well as email accounts. This greater flexibility opened the door to more distributed use: 56% percent of teachers in the thin client school said they access the network from home – a markedly higher rate of home-to-school interaction than at the LAN1 school (13%) or the LAN2 school (38%).

It is also noteworthy that ClassLink’s delivery of ubiquitous access to students and teachers may be more reliable than that of other networking solutions. During the course of our study, maintenance and troubleshooting tasks caused interruptions of a week or more in the ubiquity of access in both non-thin client schools. At the LAN2 school, the switchover from one operating system to another – a lengthy process as each machine on the network had to be individually upgraded – temporarily deprived teachers and students of the ability to easily open their password-coded network accounts. At the LAN1 school, troubleshooting delays on the school servers were a longstanding obstacle to network access. Maintenance and troubleshooting delays are inevitable with any infrastructure, but perhaps because the thin client school’s network has fewer components to be serviced, universal access to the network seems to be more stable.

**What is the role of flexible distribution of hardware in achieving ubiquity?**

ClassLink’s ability to access saved work, software and communications from anywhere on the network (or, remotely, from any Internet-ready computer) is one aspect of ubiquity that can be beneficial to school computing. Another aspect of ubiquity is access to “equipment [that is] pervasive and conveniently located” (NCREL, 1995). A fully ubiquitous infrastructure should not only provide users access to the network from any location, but should also grant teachers access to adequate hardware whenever and wherever they need it. Few schools, though, can afford a one-to-one student-to-computer ratio.

During the course of our research we observed mobile computing as a strategy for creating a ubiquitous and flexible infrastructure. There are wireless, mobile shared-computing resources in both the thin client and LAN2 schools. In the thin client school, the technology coordinator is currently using mobile shared-computing in four classrooms. In the LAN2 school, the technology coordinator has set up two mobile laptop carts on each floor of the building. Each cart – which has 10 laptops with wireless connections to the school network – can be wheeled into any room, giving teachers 10 - 20 additional machines when they need them.

Our research indicated that teachers felt that access to a class set of computers in the classroom was an important resource allowing them to do frequent technology projects. One 7th-grade teacher at the LAN2 school described the impact that mobile wireless labs have had on her teaching:

> *The laptop carts enable somebody to integrate technology a lot easier. Before, we had 4 or 5 desktops in a classroom, which limits what you can do. It was too much of a logistical nightmare before to utilize the desktops. I did it - I had my kids on a daily rotation – but I always felt like my kids were losing something to use the technology. You have to realize that one kid gets a period a week when you have a few desktops, whereas now [with mobile labs] I can have a whole class do a project in a week.*
>
> *Now…I do three or four technology projects this marking period. They're doing one right now."*

Other teachers we spoke with consistently echoed these comments. Even teachers from other schools felt shared access to mobile computing resources might be beneficial. One teacher expressed her interest as follows, "I can't do whole-class activities [in my classroom], but [my students] can do that in the lab. At [the LAN2] school they have laptops for the entire class and they're able to do the entire class which is awesome."

## Management of student work products

Working with technology can add complications to the basic and essential classroom tasks of organizing, storing and retrieving student and teacher work. Hard drives and servers can run out of space, multiple versions of a particular work product can be lost amid a vast network of folders and drives, floppy disks can break or be lost, and files – if not protected – can be copied or tampered with. The infrastructure needs to support teachers as they work with children of all ages in classrooms. The different infrastructures we studied bring varied solutions and problems in the area of saving and accessing work. Teachers in the thin client school report that they experience markedly fewer instances of several important technology-related problems that can impede technology-supported work with students.

**How does thin client impact managing student work?**

We surveyed teachers and students about three common challenges to using computers in school situations: being able to save work and being able to find that work again, and being able to keep track of revisions and updates. Teachers in the thin client school felt more confident that students can manage their work on the network than did teachers in the other schools we studied.

Fewer thin client teachers (5%) reported that their students "often" have trouble saving their work, compared to the LAN1 school teachers (21%) and the LAN2 school teachers (27%). Fewer teachers in the ClassLink infrastructure reported having frequent problems with students losing their computer work. Only 2% of thin client teachers reported that their students "often" lose their work, compared to 21% in the LAN1 school and 15% in the LAN2 school.

Another challenge for students and teachers doing computer work is keeping track of revisions and changes. Fewer thin client teachers (10%) reported that their students often have trouble keeping track of revisions, compared to 21% in the LAN1 school and 27% in the LAN2 school.

**TABLE 10: TEACHER PERCEPTIONS OF PROBLEMS SAVING AND RETRIEVING INDIVIDUAL STUDENT WORK.**

| | How often do students have trouble saving? (percent responding often) | How often do students have trouble keeping track of revisions?(percent responding often) | How often does work get lost? (percent responding often) |
|---|---|---|---|
| Thin client (n=75) | 5% | 10% | 2% |
| LAN 1 (n=38) | 21% | 22% | 21% |
| LAN 2 (n=45) | 27% | 23% | 15% |

The students' perceptions mirror those of the teachers. Students in the thin client building perceive fewer difficulties finding their work and keeping track of revisions as they work with multiple versions of a document. Among the sixth graders, 11% in the thin client environment report sometimes or often having trouble keeping track of revised work while 57% and 46% of students in the other environments reported experiencing problems with revisions. Only 2% of the students in the ClassLink environment report often losing their work, compared to 15% and 35% in the other environments.

**TABLE 11: STUDENT PERCEPTIONS OF PROBLEMS SAVING AND RETRIEVING THEIR OWN WORK.**

| | How often do you have trouble keeping track of revised computer work? (percent responding sometimes or often) | How often does work get lost? (percent responding often) |
|---|---|---|
| Thin client (n=134) | 11% | 2% |
| LAN 1 (n=103) | 57% | 15% |
| LAN 2 (n=91) | 46% | 35% |

### How does thin client impact managing group work?

Organizational and logistical challenges can multiply when teachers work with groups of students – multiple students have multiple copies of group projects, students working on different machines and in different programs need to merge documents, files get lost, or members of student workgroups are absent. When students collaborate on group work, each student on a team needs to be able to access work in progress, and all students need to be able to find the latest draft of their group product.  Teachers, too, may wish to see drafts and revisions of group work.

Enabling each member of a student team, and their teacher, to easily share, store, and keep track of multiple revisions of a product is an infrastructure challenge, particularly if students wish to work at home.  There exists the possibility for students to revise work on multiple, incompatible platforms, for work to be saved on floppy disks that are lost or will not open, or for group work to be delayed if only one student is in possession of the latest draft.  If teachers are collaborating (team-teaching), there is further need for easy sharing and accessing of saved student work.

Across the three indicators that we surveyed, the ClassLink school reports a relatively low level of problems. Less teachers (8.9%) in the thin client school report difficulty saving group work than in the other schools (12.9% and 25%).  Although, more teachers in the thin client environment report more frequent problems losing group work or tracking revisions than in the LAN 1 school, their rate is substantially lower than in LAN 2 school. This may be linked to the difficulties LAN 1 was having keeping its server working and many teachers were saving work on diskettes.

**TABLE 12: TEACHER PERCEPTIONS OF PROBLEMS SAVING AND RETRIEVING GROUP WORK.**

| | How often do students have trouble saving GROUP work? (percent responding often) | How often does student GROUP work get lost? (percent responding often) | How often do students have trouble keeping track of revisions on GROUP work? (percent respond ing often) |
|---|---|---|---|
| Thin client (n=75) | 8.9% | 5.7% | 10.7% |
| LAN1 (n=38) | 12.9% | 3.4% | 6.5% |
| LAN2 (n=45) | 25% | 19.5% | 20.9% |

**Is students' work hampered by technology-related problems?**

In interviews, teachers talked about problems with students working across platforms or creating work in different versions of the same software.  We surveyed teachers in all buildings about these issues.  Sixty-eight percent of thin client teachers said that students "seldom or never" hand work in late due to technical problems, as opposed to 58% (LAN1) and 49% (LAN2).  Additionally, only 4% of thin client teachers said they "often" had to deal with student work created on one platform (Mac or PC) that would not open in another, as opposed to 16% in the LAN1 school and 12% in the LAN2 school.  Working across multiple versions of the same software was also less of a problem in the thin client school. Only 5% of thin client teachers said they "often" had problems with student work created in one version of a software product that would not open in another version, as opposed to 16% at the LAN1 school and 20% in the LAN2 school.

**TABLE 13: TEACHER PERCEPTIONS OF TECHNOLOGY-RELATED PROBLEMS.**

| | Is students handing work in late due to technical problems a problem? (percent responding seldom or never) | How often does student work created on one platform (Mac/PC) not translate to another platform? (percent responding often) | How often does student work created in one version of software not open in another version? (percent responding often) |
|---|---|---|---|
| Thin client (n=75) | 68% | 4% | 5% |
| LAN1 (n=38) | 58% | 16% | 16% |
| LAN2 (n=45) | 49% | 12% | 20% |

In the two schools with central server-based infrastructures, saving and sharing group work appears to be more problematic than saving and sharing individual work. These two infrastructures offer teachers multiple options for helping students share work (see Table 13, below). However, teachers in these two schools report more difficulty in managing students' group work than at the LAN1 school (see Table 13, below).

**What is the relationship of centralized computing to students' accessing one another's work?**

Another concern for teachers is keeping students' work safe from being stolen or tampered with by other students. The survey data paints conflicting pictures of the relative frequencies of these problems in the thin client and non-thin client schools.

Overall, the thin client teachers reported similar frequencies of students accessing and tampering with each other's work as teachers in the other environments. Teachers in the least centralized network (LAN1) report the lowest level of concern (10%). This issue may be of slightly greater concern in the more centralized networked environments because all student work is housed in universally accessible locations (even though password protected). Only 13% of thin client teachers said that student work is "sometimes" or "often" stolen or copied by other students. Fifteen percent of teachers in the LAN2 school felt that copying is a problem. These differences hold true on the issue of tampering as well: 16% of teachers in the thin client environment perceive a high frequency of tampering and 21% of teachers at the LAN2 school see tampering as a frequent problem. Only 10% of the teachers at the LAN1 school perceive tampering as a problem.

**TABLE 14: TEACHER PERCEPTIONS OF PROBLEMS WITH WORK BEING STOLEN OR ADULTERATED.**

| | How often do students have work stolen or copied? (percent responding sometimes or often) | How often does student work get tampered with? (percent responding sometimes or often) |
|---|---|---|
| Thin client (n=75) | 13% | 16% |
| LAN 1 (n=38) | 10% | 10% |
| LAN 2 (n=45) | 15% | 21% |

Data from the student survey offers a safer impression of the thin client environment. Few students at the thin client school perceive either copying (6%) or tampering (2%) as problems. The results are markedly higher in the other two buildings. For example, 53% of the students in the LAN2 school feel that having work stolen or copied is a problem. The data provides no clear explanation for the difference between student and teacher responses, or the differences between schools. One speculation is that the streamlined access process of ClassLink where students can only access their own account whenever they log on to the environment gives the students a deeper sense of security.

**TABLE 15: STUDENT PERCEPTIONS OF PROBLEMS WITH WORK BEING STOLEN OR ADULTERATED.**

| | How often do other students steal or copy your computer work? (percent responding sometimes or often) | How often do other students tamper with you computer work? (percent responding sometimes or often) |
|---|---|---|
| Thin client (n=134) | 6% | 2% |
| LAN 1 (n=103) | 37% | 27% |
| LAN 2 (n=91) | 53% | 44% |

## Communication Patterns

The organization of a high performing technology infrastructure should facilitate communication and collaboration among users. We asked students and teachers about their technology-facilitated communication habits. How often did they make use of the school's infrastructure to communicate? From where and with whom did they communicate?

**Are teachers using the thin client network to communicate beyond the classroom?**

As reported above, 56% of teachers in the thin client school said they access the network from home – a markedly higher rate of home-to-school interaction than at the LAN1 school (13%) or the LAN2 school (38%). However, thin client teachers were not yet tapping into the network's potential to enable communication with students and parents via email. Eighty-nine percent of the teachers said they "never" or "seldom" exchange email with individual students; 97% said they "never" or "seldom" send group emails to students; 82% said they "never" or "seldom" use email to contact students' parents or guardians; and 97% and 99%, respectively, said they "never" or seldom" use email to assign or collect homework from students.

**Are students using the thin client network to communicate beyond the classroom?**

Although the thin client school's ClassLink system provides each student with an internal-only email account, only 78% of the 6th-graders who responded to our survey said that they have an email account or address. This may mean that a number of students do not use those accounts and are, in fact, unaware that they have them. These numbers compare to 67% and 45% of students reporting email accounts in the LAN2 and LAN1 schools, where students are not provided with school email accounts. Students in the thin client school were most likely to email their friends, 79% said they "sometimes" or "often" email their friends (as compared to 63% at LAN2 and 53% at LAN1). The next most common correspondences occurred between students and their families: 57% said they "sometimes" or "often" email their family (as compared to 61% at LAN2 and 47% at LAN1). Use of email for schoolwork was notably less common, though it was more common at the thin client school than at the other two schools: 15% said they "sometimes" or "often" email their teachers (as compared to 1% at LAN2 and 14% at LAN1); 46% said they "sometimes" or "often" email their classmates for schoolwork (as compared to 41% at LAN2 and 29% at LAN1).

## Infrastructure and the school budget

Both district and school administrators felt that ClassLink lowers their technology budget. Although they had not seen information on the Total Cost of Ownership (TCO)[4] of thin client networks in schools, district administrators felt confident that ClassLink was a cost-effective means to create a technology-rich learning environment. They identified a number of ways that ClassLink saved money.

### *Implementing thin client: broad costs and savings.*

The initial costs of implementing a ClassLink thin client network are high, but within two years the system costs drop dramatically. To install a ClassLink network at the thin client school, the Union City school district paid roughly $190,000 in the first two years, including $440 for each new thin client terminal and a $420 combined licensing fee for Microsoft and ClassLink for every machine on the network. The costs of bringing the school's preexisting computers onto the network was only the licensing fee. In subsequent years, the recurring cost has been a $30,000/year maintenance contract, which covers technical support for the network and thin client terminals. The school retains an additional technician to service its non-thin client machines. However, both

[4] "Total Cost of Ownership" TCO - a concept borrowed from the business world — consists of all costs incurred during the life cycle of an asset, including purchase, deployment, operation, support, and disposal. By identifying and quantifying all the costs of technology – long- and short-term, obvious and hidden – administrators can do a better job of reducing those costs by anticipating needed investments before they become expensive crisis-management (COSN, 2001).

the school and district technology coordinators feel that the thin client school is still saving money on technical support – getting the equivalent of two technical support staff for less than the cost of one and half staff.[5]

**Hardware obsolescence and breakage: thin client costs and savings.**

Because the thin client system runs software on a central server, older computers with out-of-date CPUs can function as effective workstations and many technical problems can be centrally serviced. The thin client school technology coordinator reported that the low cost of maintaining this centralized infrastructure has allowed her to allocate funds toward professional development: "My repair bill has gone down really low because of thin client. The hardware doesn't suffer as much…. Teacher training is where my money goes." In contrast, the technology coordinator at one of the LAN schools estimated that she "usually pulls about 30 machines off the floor a year."

**Can a pure thin client network address the full spectrum of a school's technology needs?**

The school and district could have made the decision to create a full environment of only thin client terminals. This option would offer substantial savings in the entire cost of hiring technical support staff (for troubleshooting) by eliminating all full-capacity computers from the system. However, the school and district technology administrators decided to maintain a mix of computing resources in the building.

The first reason that the technology decision-makers gave for selecting a mixed environment is the need for diversity of software. The ClassLink desktop is a Microsoft Windows-equivalent operating system that runs a vast array of software but does not support software that is not NT compliant. The ClassLink system does not fully support a number of educational software packages that were commonly used in Union City, such as kid-friendly word processors like the Bank Street Writer. The technology coordinator at the LAN2 school, where teachers commonly use a broad range of instructional software, described this as a major reason why she had resisted adopting a ClassLink infrastructure. At the thin client school, the technology coordinator deals with the issue by maintaining a complement of full-capacity computers throughout the building that can run on the network as ClassLink terminals and be taken off-line when needed.

A second reason for maintaining some full-capacity computers on the network is the need to circumvent the limitations of thin client terminals in supporting certain kinds of peripheral devices. Again, the thin client school technology coordinator has maintained full-capacity computers for the youngest students who sometimes need to use one-button mice, headphones, and to record sound.

Although she reports a mostly trouble-free experience since installing the thin client network, the thin client school technology coordinator reports that she prefers to maintain a number of full-

[5]Based on the district's average salary for tech support staff of $100,000/year; the district pays $130,000 for one technical support person and the ClassLink contract, rather than $200,000 for two staff.

capacity computers through out the building as a backup system. "Buying thin client terminals is cheaper," but she feels the need for "the luxury of disaster recovery;" if her server goes down, the full-capacity machines will still be available for use.

These factors have led Union City technology staff to seek what the district director of technology calls "the right mix" of thin client terminals and full computers. Creating this balance of inexpensive thin client terminals and full-capacity computers is this district's strategy for reaping the benefits of thin client's centralized infrastructure while maintaining access to educational technology not supported by the ClassLink system.

## CONCLUSION:

*"A school's vision of the education it strives to provide students contains many elements, of which technology is but one."*

*(Planning for Data-driven decision making about technology. NCREL. 1999)*

Everything the education community knows about supporting and creating rich learning environments with technology indicates that non-infrastucture factors like curricula, pedagogical vision, professional development, on-going instructional support, and administrative leadership are primary components to success (Becker & Ravitz, 2001; Ely, 1990; Means, 1994). An effective, functional infrastructure is a necessary but not sufficient condition for a rich technology environment. In the best technology environments, the technology itself fades into the background, allowing teachers and students to focus on learning (Hawkins et al, 1996). The questions we considered in this study were whether ClassLink reduces common obstacles and impediments to technology integration, and if its central server structure affords other valuable opportunities to teachers and students. In nearly every dimension we investigated, the answer is an unqualified yes.

- **Access.** ClassLink provides a ubiquitous, interconnected environment that enables teachers and students to have access to their own folders, the same software, and the same resources from anywhere in the building and from anywhere else via the Internet.

- **Operability.** The thin client environment supports the Microsoft Office Suite (Word, Excel and PowerPoint) and many programs the teachers at the thin client school use in their classrooms. Certain peripherals, software and multimedia capabilities presented a challenge to the architecture of the system but ClassLink and the technology coordinator at the thin client school together developed strategies to integrate peripherals and missing software into the school's learning environment. First, ClassLink developed scanner bays that tie scanners into the network. Second, the school maintains a number of full-capacity computers distributed throughout the building that can move on and off the network and run software or access peripherals locally. In the Union City director of technology's words, the key to extracting maximum benefits from the ClassLink system is to find the "right mix" of terminals and computers.

- **Organization.** The ClassLink environment effectively supports collaborative work among students by reducing the technical problems of saving, retrieving and organizing group files among students. thin clients are also a networking solution that easily distributes computing resources throughout a building. The flexibility would be increased by the addition of laptop carts to the thin client environment.

- **Engagability.** ClassLink frees the technology coordinator and support teams from intensive troubleshooting, which can allow them more time to support and train teachers to integrate the technology into the curriculum. The human infrastructure and the capacity of the technology coordinators play a central role in increasing engagability.

- **Ease of Use.** Teachers and students perceive ClassLink as a stable and reliable system. Teachers also find that the ClassLink system is easy to use and facilitates key tasks like saving and retrieving student files.

The greater the variety of software and infrastructure options that ClassLink's thin client network can support, the more effective this product will be in enabling schools to effectively integrate educational technology. Administrators implementing ClassLink's thin client infrastructure also need to be strategic about providing the "right mix" of hardware, software and networking options to address the broadest possible range of educational needs.

The overall results of the evaluation indicate that ClassLink's thin client system simplifies the work of maintaining and troubleshooting hardware and software, makes it easier for students and teachers to organize and access technology-supported work, and appears to decrease the cost of maintaining the network and dealing with hardware obsolescence. These characteristics of the thin client system are effective solutions to problems that commonly plague school and district technology infrastructure.

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