

Configuration of School Technology Strategies and Options

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The demand to integrate computers into education forces education planners, principals, teachers and technology specialists to make many decisions about the technical, training, financial, pedagogical and infrastructural requirements of school computerization programs. One of the more challenging clusters of questions that planners and educators must make center on the concerns of where and how computers should be distributed, connected and used in schools. There is no single *best* computer configuration.¹ Rather, there are only optimum solutions for each school.

Educational Context: Needs and Approaches

Each school or school system must evaluate its situation and educational needs and compare the costs and benefits of a variety of computer system configuration options. In carrying out an assessment, the following questions may need to be considered:

- ❖ What are the educational goals and learning objectives for using computers in schools? Different computer configurations have a direct relationship to how computers and the Internet can and will be used by teachers and students to enhance education.
- ❖ What is the target ratio of computers to students that the school or school system is aiming for?
- ❖ Will a school's computer system need to be used by members of the community during non-school hours? The high cost of investing in technology in public schools will often be partly justified by allowing the new computer facilities to be used by members of the school community. If this is a priority, then a lab or computers-on-wheels configuration may be needed.
- ❖ What are the physical characteristics of the school building? This includes the types of building materials used in the walls, the availability and quality of electrical power, the size and shape of classrooms, the quality of natural or electrical lighting, the availability of telephone lines, and the types of furnishings?
- ❖ How secure are the school and the classrooms in which computers may be installed? Is the risk of theft high? Providing sufficient security to prevent theft of equipment, software and supplies is expensive and it is often only possible for one or two rooms in a school.
- ❖ What is the average number of students per classroom and a projection on how this ratio may change over time? Schools that have large numbers of students per classroom will likely have limited space for computers to be permanently installed.
- ❖ What strategies will be used to provide support, management and maintenance of the computer facilities?
- ❖ How much money is available to purchase and install the equipment, buy software, and train teachers? Is there a budget for on-going maintenance, supplies and technical support, and for replacing aging equipment and increasing the number of computers in the school? Technology budgets for initial installations of systems and on-going support will likely be a dominating factor when deciding which configuration is *best* for a school or school system. This is especially true for older schools that may need to have special electrical systems installed for computers, and for crowded schools with poor general security, which may need to install special doors and window grates to prevent theft.
- ❖ Do the teachers know how to use the computers and, more importantly, do they have the skills to integrate computer and Internet use into routine teaching and learning? Most investments in computers and Internet access in schools are done both to provide opportunities for students to learn about using computers and to enable the overall quality of teaching and learning to be improved. The physical technology by itself cannot achieve these goals. Only skilled teachers can. Integrating technology into education often requires teachers to change their approach to teaching and their interaction with students. The configuration of computer facilities in a school has important relationships to the training and professional development needs of teachers and affects teachers' abilities to use technology to achieve the educational goals of the investment.
- ❖ Do students move from class to class throughout the day or do they spend most of their time in one room?
- ❖ Will the computer system be used by special needs students? Is physical access to computers by students in wheel chairs an important issue?
- ❖ Will rooms with computers need to be air-conditioned or

protected from excessive dust in the air?

- ❖ Will the computers be connected by cable or wireless systems to form a network, and will this local area network (LAN) require a central computer or server to manage network activity?
- ❖ Will the computers be connected to the Internet? If yes, what type of connection (intermittent use of normal phone cables, dedicated phone or cable connections) will be possible?

These questions are not equally important. So, the answers should be accordingly weighted. One of the most difficult challenges, though, is balancing educational objectives with hard financial realities. Ultimately, the goal of an assessment is to determine the optimum configuration for integrating computers into education at a specific school.

There are many ways to categorize and describe the different computer system configuration options and strategies. In this article, we use three organizing themes:

- Physical configuration options
- Networking technology options
- Internet access options

Physical Configuration Options

There are three basic ways that computers can be distributed in schools to meet educational goals. They can be provided to individual classrooms, installed in central computer labs and placed in libraries and teachers' planning rooms. Each of these options, and their combinations, has associated benefits and costs that need to be carefully considered. Some educational technology specialists argue that proximity and easy access to computers are dominant factors in achieving high rates of use by students and teachers and thus positive educational benefits. Similarly, some people consider that installing computers in central computer rooms or labs is "old fashioned" and inhibits effective educational use. These are overly simplistic perspectives since the distribution of computers is only one factor determining how teachers use computers and the Internet to enhance teaching and learning. Teachers can use each of these configuration options to help enhance education. The most critical factor is the teacher, not the physical configuration of computers in a school. Configuration can, however, affect teachers' access to computers and their options for how technology can be used.

Computers in Classrooms

One of the greatest potential benefits of distributing computers to individual classrooms is to provide teachers and students with easier access to these educational tools. This can make it potentially easier for teachers to integrate computer and Internet use into routine educational programs. But it cannot be guaranteed. Also, not all schools and classrooms

can accommodate computers in sufficient numbers. Providing only one or a few computers in all classrooms of a school will likely have little or no impact on learning since it will be difficult for teachers to make computer use an integral part of their teaching.

Important considerations for classroom computer installations:

- **Teachers' skills:** Computers in classroom configurations usually require teachers to have a high degree of technical skills along with the capacity to dynamically integrate the use of computers into their teaching. This combination of technical skills and pedagogical capacity is not common and without it investments in classroom computers can lead to negligible educational gains.
- **Space and student numbers:** Placing clusters of computers in a classroom to enable effective student use requires enough space for groups of two to three students to sit comfortably in front of the computers. Space is also needed to give teachers enough room to move among the groups to orchestrate activities. Furthermore, incorporating computers into regular classrooms usually requires non-traditional student seating arrangements. Few schools and classrooms, especially in developing countries and poorer communities have sufficient space or the capacity to provide a low student to computer ratio to make classroom computer installations feasible.
- **Quality and availability of electricity:** Computers demand a quality electrical supply. Classrooms in older schools often do not have access to quality electricity or to electrical systems with the capacity to support 12 to 20 computers. Remodeling classrooms to meet the electrical needs of computers is usually very expensive, especially if it needs to be done for many classrooms.
- **Security:** Classrooms in many schools are often used for many purposes throughout the day and week. Maintaining sufficient security to prevent theft of equipment, software and supplies while also enabling open access to the classrooms to a variety of users is usually not possible. Also, modifying the doors and windows in the classrooms to make them secure can significantly increase the cost of installing computers in a school.
- **Availability of maintenance and support services:** Distributing computers throughout the classrooms of a school will make it more difficult and therefore more expensive to provide effective maintenance and support services. This is especially true in systems where teachers lack the skills and time to provide these services on their own.
- **Internet access:** Access to the Internet can multiply the educational impact of computers many times. However, few schools have the capacity to provide

Internet access to all classrooms. Providing even limited Internet access via intermittent use of a single dial-up connection via a phone line can significantly increase the cost of school computing. Enabling high-speed access to all computers in a classroom can be prohibitive.

- **Connecting computers within the classroom and the school:** As with Internet access, connecting computers together in a classroom and school to form an electronic network can multiply their usefulness and increase their educational impact. Without being networked, computer use is limited to simple one-to-one and small group activities, routine word processing, and the use of stand-alone reference and educational software applications. Unfortunately, most schools require extensive remodeling to enable computers in classrooms and schools to be connected to form networks. Also, creating classroom networks in schools can require significant investments in additional computer hardware (servers, hubs, switches, routers, etc.).

Alternative Computers in Classroom Strategy—COWs

COWs or Computers On Wheels are carts that hold a set of computers (10 to 20), usually laptops, often a printer, with the possibility to connect to a school network via one network connection. COWs can be wheeled into a classroom when the teacher wants to use computers for a specific activity. Some of the benefits and challenges of using COWs are discussed below.

Benefits:

- COWs make it possible to provide teachers access to computers in their classroom without having to significantly remodel the room, provide special furniture, or reserve space for dedicated computers.
- Working in small groups at their desks enables all students to have access to computers even in crowded classrooms.
- Using battery-powered laptops makes it possible to avoid the need to provide special electrical power.
- Using infrared printing and wireless networking cards enables the students to print their work and connect to the school network for e-mail communication and possibly access the Internet without the need for cables.
- COWs allow schools to optimize the use of expensive equipment by enabling any teacher to request a cart of computers.
- COWs may be more affordable than the costs to remodel classrooms, provide special electrical supplies, install cabling to network all the computers, buy furniture, and purchase the computer equipment.
- Since software only needs to be purchased for the computers on the carts and not for dozens of computers in

each classroom, the cost for software can also be much less with COWs than with conventional classroom computer installations.

- COWs can be stored in secure rooms when not in use.
- COWs can provide classroom access to computers in situations where students have classes in different rooms.
- COWs can be customized to include expensive specialized equipment that normally would not be part of a classroom system.
- COWs can be used in support of teacher professional development programs.

Challenges:

- The initial cost of COWs with laptops and wireless networking capabilities has a higher cost per computer than conventional stationary computers.
- COWs can be seen as “communal” property and therefore it can be more costly to maintain them, especially when using laptops, than with stationary systems.
- There is a greater risk of equipment damage from accidents, hard use or dropping with COW using laptops than with stationary equipment.
- Dedicated staff is often needed to maintain COW systems, deliver them to teachers, and help teachers set up and use the equipment.
- Schools with multiple floors without elevators either have to have COWs for every floor or restrict their use to specific floors. Similarly, schools comprised of different buildings may not be able to use COWs.
- The difficulty of scheduling the use of a limited number of COWs may frustrate teachers and inhibit them from using these systems.

Computer Rooms or Labs

Establishing one or more computer rooms or labs is a popular way to provide equitable access to computers for the greatest number of users at the lowest possible cost. Computer labs enable schools to concentrate expensive resources in a common space that can be used for student educational activities, teacher professional development events and community groups. When using computer labs, it is important to arrange computers along the walls of the room rather than in rows so that teachers can view all the students’ work from a common point and move quickly and easily from student to student, providing feedback and support. It can also make it easier and less costly to provide electricity and network access to the computers. Some of the benefits and challenges of using computer labs are discussed below.

Benefits:

- Establishing a computer in a lab or dedicated room only requires schools to install quality electricity, network cabling and servers, effective security, climate control

systems, good lighting, and specialized furniture in one or two rooms in a school rather than in many different rooms.

- A dedicated room, if effectively designed, ensures that there is sufficient space to allow students to work in groups, move about to see each other work, while also allowing teachers to move from group to group to provide input and guidance.
- Computer labs can be maintained by one or two staff that can also provide teachers with technical and pedagogical support.
- Equipment and software costs can be less for computer labs used by all classes than by classroom-based systems.
- Computer labs can optimize return on technology investments.
- It can be easier and less costly to provide access to the Internet via computer labs than with classroom systems.
- Computer labs can make it easier to encourage collaborative projects among groups of teachers and students.

Challenges:

- Computer labs can quickly become oversubscribed and competition for use may make it difficult for teachers to engage their students in longer-term on-going projects and activities.
- Scheduling conflicts can frustrate teachers and inhibit their use of computer labs.
- Users, as with COWs, can see computer labs as a communal resource and thus reduce the feeling of responsibility and make it more difficult to maintain.
- Once the novelty of using computers wears off, encouraging teachers to move their students to the lab may become increasingly difficult.
- Spontaneous needs to use computers for research, reference, word processing, etc. can be impossible or very difficult to act on.
- In some schools, principals or lab coordinators may implement policies that can limit access to the computers.

Computers in Libraries and Teachers' Rooms

When funding and staff resources are scarce, schools can optimize investments in computers and Internet access by installing a few computers in public spaces such as the library and the teachers' planning room. Giving teachers private access to computers and the Internet can encourage teachers to learn to use these technologies and enable them to carry out planning activities involving the use of computers.

Hybrid Options

Where possible, the greatest educational returns on technology investments can result by strategically using combinations of the above configuration options. For schools with

sufficient room, suitable infrastructure, funds and technical resources, the strategy of distributing computers to classrooms either as stationary systems or via COWs can be an effective means of enabling easy access to computers and the Internet. Library computers can be used to focus on research activities, while special classrooms can be outfitted with computers, especially for special needs students, to enable and enhance benefits that are difficult to achieve from computer labs. The combination of these two options with one or more computer labs can create an ideal solution to providing students and teachers with rich and powerful educational tools.

Networking Technology Options

Connecting computers together to form a network and connecting school, lab and classroom networks to the Internet can significantly multiply the educational value and impact of computers in schools. There are a variety of options for creating classroom, lab and school computer networks.

Peer-to-Peer Networking

As with all networked computers, users can share files and resources located on computers in the network. With peer-to-peer (p2p) (see **Figure 1**) networking, however, there is no file server or central computer that manages network activity. One or more of the computers in a p2p network can provide centralized services such as printing and access to the Internet. Most desktop operating systems come with software to enable p2p networking once the computers are connected by some cable or wireless-networking infrastructure.

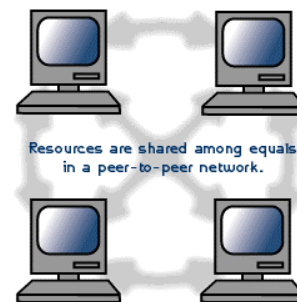


Figure 1: Peer-to-Peer Network²

Peer-to-peer networking is good for small networks where a centralized file server is not needed and where network security is not a major issue. This type of networking is less expensive to set up since the only expense is in the cables and networking hardware. However, as the network of computers grows in size and complexity, it will likely be necessary to shift to a client/server style of network.

Client/Server Networking

Larger networks in schools are client/server networks. In these networks, as seen in **Figure 2**, one computer centralizes functions of storing common files, operating network e-mail delivery and providing access to applications.

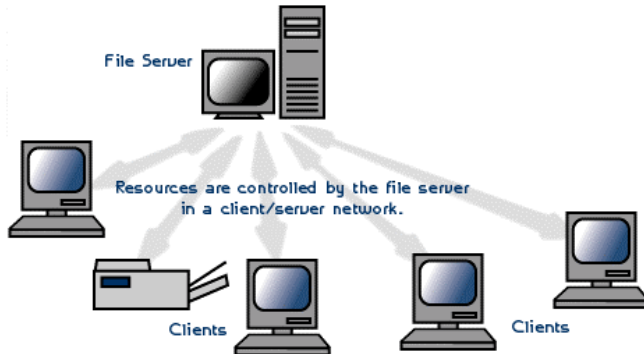


Figure 2: Client/Server Network²

One of the advantages of client/server networks is that they are scalable; you can add more clients and servers to the system without significantly changing the network. Centralizing network services can also make the network easier to manage and administer and client/server networks provide a greater degree of security than do p2p networks. These benefits come with some disadvantages. Because of the dedicated server, initial costs are higher and they are more complex to set up and maintain than stand-alone computers and p2p networks, often requiring schools to hire a network technician to oversee the network. Also, if the server fails, all network functions fail.

Thin-Client/Server Networking

A thin-client/server network is similar to a traditional client/server network except that the client is not a free standing computer capable of operating on its own. In contrast, thin-clients are desktop appliances or network devices that link the keyboard, monitor and mouse to a server where all applications and data are stored, maintained and processed. The server, often called an application server, is built to provide all the networking services and computer calculations. Since all network and computer services are centralized, all maintenance and upgrading is done at the server; there is no need to service the clients.

Proponents of thin-client/server networks emphasize that even though initial purchase costs are usually higher than with traditional PC/server networks, lifetime costs or total cost of ownership (TCO) can be significantly less. For example, a recent "survey of 25 [business] sites using thin-client technologies conducted earlier this year by Datapro concluded that on average, deploying thin-client devices cut support [life time] costs by more than 80 percent."(Molta,

Dave, June 28, 1999)³ The primary reason for a low TCO is savings from centralized management, often from centralized remote sites, and from less costly upgrades in software and applications. Thin-client/server networks are also easier to install than traditional client/server networks. Also, since the client appliances cannot function without the server, there is little risk of theft. Thin-client systems are very efficient at providing access to the Internet. Because the client appliances have few moving parts and limited functions, thin-client/server networks are more reliable and stable than traditional network systems.

A major disadvantage for some thin-client/server networks is that little educational software is written to run on thin-client servers running a version of UNIX. Most of these servers come with special emulation software but this is usually an incomplete solution and software often runs slower and some applications fail to function. Since many thin-client/server networks are based on a type of Unix operating system, skills with Unix are needed to set up and administer. However, if schools have no staff with these skills but have access to the Internet, it is possible to have a technician at some remote site administer and maintain the network. This enables a school district to have one highly skilled technician manage thin-client/server networks in several schools thus reducing management costs further.

Even though thin-client/server network systems are relatively uncommon in K-12 educational environments, they are a viable alternative to traditional client/server network systems. A careful assessment of TCO and the availability of technical skills at a school or school system can help planners decide if the thin-client/server network is best for their needs.

Connecting Computers

There are essentially three ways to connect computers together to form local area networks. The most common is to use some form of cable, either standard phone cables, coaxial cables or 10/100BaseT twisted pair LAN cables. Of these, the most common cable option today is 10/100BaseT Ethernet networking. Installation usually requires cables and ports to be installed in walls, floor or ceilings.

An option to installing special network cables that has recently become a reliable technology for some situations is to use the existing power lines in the school to carry the network traffic. Presently, Power Line Networking (PLN) is capable of providing reliable network communication speeds between 250Kbps and 500Kbps for six to 20 network access points. Higher speed systems ranging from 2 to 12 Mbps are also available. Equipment costs are presently higher than conventional networking technologies. These prices are expected to fall as technical improvements are made and larger scale systems become available. In some situations, the costs

of using PLN can be less than installing cable systems.

Another network option that is becoming increasingly popular and affordable is wireless local area networking. Such systems use a variety of communication frequencies to enable reliable connections at a variety of network speeds from 2 to 11 Mbps across distances ranging from 30 to 500 meters. For small local area networks or portable classroom systems, wireless connectivity is often a viable and cost-effective option in comparison to cabling older buildings. Wireless networking also provides a degree of flexibility that is not possible with cable systems. Also, since cables do not need to be installed, a network can be created in a very short period of time.

Internet Access Options

One of the most important educational benefits of computers is that they enable access to the Internet and can be used as powerful communication devices. There are a variety of options and technologies that should be considered when deciding about Internet access. This section only introduces Internet access options. These and other options are further detailed in Heather Hudson's article, "Solving the Connectivity Problem," in this Issue of *TechKnowLogia*.

Simulated Internet

If a direct connection to the Internet is not possible either for economic, technical or availability reasons, it is possible to provide students and teachers with simulated access to a selection of Internet resources by copying valuable web sites to CD-ROMs (CDs) and then using the CDs. For example, the Rio de Janeiro Municipal school system provides schools that cannot directly access the Internet with a CD containing a selection of Portuguese language educational web sites. The CDs, which are periodically updated, use the same Internet browsers that are used with the Internet so that when Internet access becomes available, teachers and students will have no difficulty using this technology. The "Internet" CDs can also make it easier for teachers to prepare structured educational activities; students can explore the CD but cannot surf beyond the scope of the activity. Even if Internet access is available, using a CD with copied web sites can make it easier for students to use a slow connection.

Dial-up Connection

The simplest and lowest cost connection to the Internet is through dial-up access using a single standard phone line. This can either provide Internet access by a single computer in a lab, class room, teachers' room or library, or by using software on a server to allow networked computers to share this single connection. However, when sharing a connection, the speed of access can become very slow since the total available bandwidth will be divided among the number computers in the network.

If two or three phone lines are available, it can be possible to combine these lines using an analog router to enable multiple phone line access to an Internet service provider (ISP), thus increasing available bandwidth.

If phone lines are not available but cell phone links are, it is possible to use a cell phone with a cellular modem to allow access to the Internet. This can be very costly and is usually limited to short burst of use for email communications.

Dedicated Connection

Schools can speed up and improve reliability of Internet access by using dedicated high-speed connections where available and affordable. There are a variety of dedicated high bandwidth options that may be available to schools including ISDN, DSL, digital cable, radio modem, and satellite access.

Concluding Thoughts

As mentioned at the start, there are no "off-the-shelf" configuration solutions to meet the diversity of needs and conditions for different schools around the world. Carrying out an assessment of needs, physical conditions, constraints and opportunities and weighting factors according to their importance, will contribute greatly to the process of deciding which type of configuration optimizes resources against needs. It is also important to examine the capacity of local markets to support different options, especially new innovative state-of-the-art technologies. Throughout the information gathering and decision-making process, it is important to evaluate options and alternatives against the ultimate objective of all school computer systems—to enhance teaching and learning.

¹ In this article, computer configuration refers to how computer systems will be distributed, arranged, connected and used in a school. The article will not discuss the technical configuration of how software is installed or how individual computers are prepared for use.

² From: "An Educators' Guide to School Networks," Florida Center for Instructional Technology, College of Education, University of South Florida. <http://fcit.coedu.usf.edu/network/>.

³ Molta, Dave, "For Client/Server, Think Thin," IT Papers.Com (<http://www.itpapers.com/cgi/PSummaryIT.pl?paperid=13855&scid=154>) June 28, 1999