Computer Networks in K-12 Education

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Section 1: Introduction

Computer networks have already revolutionized many of the institutions and endeavors that involve the creation, distribution, or consumption of information. The management structure of large corporations has flattened. Manufacturers and their suppliers work together in new ways to improve product quality and time to market. Scientists all over the country access the latest data received from NASA probes. Teams of top software engineers design computer systems together, without ever working in the same place or even at the same time. Yet, although it is hard to imagine a more information-oriented endeavor than education, K-12 schools have barely tapped the enormous potential of computers and networks - so far.

In a network of computers, one user can communicate with all of the other users of the system, examine information stored throughout the system, and run computer programs on powerful or specialized remote computer systems. The value of any such a network is a function of the number of users, computer systems, databases, and organizations already attached to the network, just as the value of a library card is a function of the number of books in the library. By almost any measure, the world's largest computer network is the Internet, which is the network on which we focus in this paper. (However, the work is also applicable to some growing regional networks.) The Internet evolved from a U.S. Defense Department communications system to become an interconnected collection of more than 46,000 independent networks, public and private, around the world (NSF, 1995). It now serves millions of users worldwide, and growth is rapid and exponential.

To aid those schools considering an Internet connection, this paper provides some examples of how schools can and are using the Internet. It describes some of the potential benefits, and presents some thoughts on obstacles to be overcome.

Much of the data comes from a project conducted here at Carnegie Mellon University to aid the Pittsburgh Public Schools (CMU, 1994). (See the Acknowledgments section.) Pittsburgh had begun a program to connect schools to the Internet known as Common Knowledge Pittsburgh, in partnership with the Pittsburgh Supercomputer Center and the University of Pittsburgh, and

with funding from the National Science Foundation. Two information sources are of particular importance for this paper. One is direct observation of Common Knowledge Pittsburgh in its first year, including teacher and administrator surveys and interviews, student interviews, and classroom observations. The other primary data source is the set of responses from a questionnaire addressed to educators using the Internet. (The questionnaire was sent to relevant newsgroups and email distribution lists. These tools are explained in Section 2.) Twenty-one responses were received describing thirty four distinct classroom activities. Given the small sample size and a method of distributing questionnaires that naturally favors frequent Internet users, statistics are not terribly meaningful. However, the deliberately unstructured nature of our questionnaire allowed recipients to describe their activities and experiences, and share their insights on the benefits and pitfalls of using the Internet. Unstructured interviews were also conducted with educators who are using the Internet. Descriptions from the printed literature of roughly 40 classroom activities were also studied to supplement interviews and questionnaire responses.

The next section will briefly describe for unfamiliar readers some of the Internet tools and resources that may be useful in the schools. Section 3 presents a taxonomy of classroom activities. Section 4 describes effects and benefits of using the Internet, while Section 5 describes difficulties to be overcome. Programs to prepare and support teachers are addressed in Section 6. Finally, Section 7 discusses the future of information technology in K-12 education.

SECTION 2: Internet Tools and Resources

This section provides a brief overview of the Internet's capabilities. The classroom activities discussed in the next section will be built upon these capabilities. For many years, three types of traffic have dominated the Internet: file transfers (FTP), telnet, and electronic mail (email). With FTP, a user can copy a file from, or to, another computer system. This file can contain any data type including text, software, pictures, and music clips. A variation called anonymous FTP allows a user to copy files without need for password privileges. Telnet allows a user to log on to a remote computer as if it were in the same room. For example, one might telnet on to a system because it has capabilities that the local system lacks. Finally, with email, a user can send a message to any other user, or set of users. The message sits in each recipient's mailbox until that recipient decides to read mail. Email is a fast and convenient way to communicate with individuals. Two variations of email also facilitate a wider distribution of messages. One is email distribution lists, which are lists of email addresses of people with shared interests. Email sent to a distribution list goes to all of these addresses. (A list of educational distribution lists is available via anonymous FTP from nic.umass.edu). Email can also be sent to a newsgroup, also known as an electronic bulletin board. The email is stored on the bulletin board, and any user interested in the topic of the bulletin board may read it much the same way one reads personal email.

A number of important tools have also been developed in recent years that facilitate the search for information on the Internet, such as Gopher, Archie, Veronica, and Mosaic. They greatly simplify research using the Internet.

The tools to search for and transfer information are obviously only useful if the network contains useful information. There is no way to describe all of the resources available on the Internet, but five illustrative examples follow. (1) The Educational Resources Information Center (ERIC) provides information on curricula, professional development, teaching methods, and educational materials. Telnet to acsnet.syr.edu, login: suvm, userid: suinfo. An ERIC gopher is also available. (2) The NASA Spacelink offers an interactive database with lesson plans, science activities, and NASA flight information. Telnet to spacelink.msfc.nasa.gov, username: newuser. (3) Digital images highlighting the photography of the Smithsonian Institution are available via anonymous FTP from photo1.si.edu. (4) Worldwide meteorological data including forecasts, records, and storm warnings, can be retrieved by telneting to hurricane.ncdc.noaa.gov, login: storm, password: research. (5) The Library of Congress Information System (LOCIS) contains over 15 million catalog records. Telnet to locis.loc.gov; no password is necessary.

Section 3: Classroom Activities

This section describes different types of classroom activities using the Internet, based on the results of our own questionnaire and a search of the available literature. All examples are drawn from actual activities. Figures 1 and 2 show the diversity of classroom activities by presenting the grade levels and subject areas of activities that were revealed through our questionnaire. Although these results are certainly not statistically significant, they do dispel the myth that computers and networks are just for the math/sciences, since these disciplines account for only 37% of activities.

Most activities we observed can be divided into three broad categories, each of which will be addressed in turn. (Of course, imaginative teachers are bound to create activities that do not fall in any of the three.) In the first category, students do work and then send it across the network to some other party for evaluation and/or response. The network provides a high-tech postal service, but with no cost per letter, minimal hassle, and most importantly, a negligible time for the message to reach its destination which enables meaningful interaction rather than monologue. This other party may be a peer, or it may be an authority figure. Beginning with the former, penpal programs are both common and effective. For example, a young student writes email messages to a peer about herself or her interests. There is strong motivation to write good letters because students enjoy receiving long, detailed letters, and are disappointed with terse replies. As one teacher states, "a good letter writer generally receives good letters." This is consistent with a 1989 study conducted by researchers from the University of California at San Diego in which teachers, in a blind comparison, found essays written for penpals to have "significantly higher ratings" than essays written for a grade. Older students can exchange more complex material like stories and artwork, sometimes critiquing each other’s work. Other penpal programs we discovered were intended to provide a forum to learn about distant events and to appreciate different ways of life. For example, students send other students first hand accounts of natural disasters, inner-city elementary school students correspond with Native American peers who live on a reservation, and Americans correspond with South African students. Email is also sometimes written in a foreign language to both motivate and help students learning that language. In summary, a teacher commented that "kids communicating

with kids across varied topics of interest is a great way to facilitate reading, writing, language development, and learning."

The Internet is also used to provide communications between students and older students or professionals. Some contacts are academic. Some students send their writing samples to professional writers for feedback, and others correspond with professional engineers for help with independent science projects. Students may also seek other kinds of support. For example, there is an activity that links disabled students with big brothers and sisters. Another connects students from schools where few go on to college with their older counterparts who are in college.

A second category of activities includes those group projects in which students at different locations collaborate. For example, students can cooperate on a difficult and creative task, like selecting tools they would bring on a trip to the moon. Such a project shows students the value of working in groups, since each classroom is bound to produce ideas that improve the group's solution. Many of these distributed projects are experimental in nature. This gives students a chance to engage in meaningful exploratory science with a large body of data. Students gather data locally, and then data from around the country (or the world) can be pooled. This way, they spend a relatively small amount of time collecting their part of the data, but they completely understand how all of the data was collected, and have a sense of ownership. For example, students are taking temperature and barometric measurements for a project on weather, surveying garbage around their school for a larger project on environmental impact, and making astronomical observations. Most of these activities are designed for older students, but there are less complex variations for younger students. For example, students in different countries gather the prices of various products. To compare prices, students must master exchange rates.

The final category of activity includes those tasks where students exploit remote data sources and processing capabilities on the network. Most often, students browse the Internet for information related to their work, so the Internet serves as an enormous library with extraordinary search capabilities. With the growing popularity of new browsing tools, such activities are likely to become more common. The remote processing capabilities can also be valuable. For example, students run computationally intensive scientific simulations on a powerful remote computer that could not be run on the school's inexpensive equipment. Such simulations can also replace expensive (or dangerous) laboratory equipment in the school.

All three categories of activities are applicable for students of all ages, but student age does matter. Most importantly, the younger students are generally given simpler and more structured tasks. For example, elementary school students are told to read a specific bulletin board for useful information on the assigned topic. High school students can select a paper topic and can search the entire network for useful sources. Also, older students are more likely to use newer and more powerful tools like gopher and mosaic, although email was the most popular tool at all grade levels.

It should be noted that activities that do not directly involve students can also be extremely valuable. Many educators have commented that the Internet allows them to improve their skills by tapping information sources on their discipline or on teaching in general, and by

corresponding with other educators around the country with similar interests. One teacher said "When I get the information I will be seeking, I can incorporate some of the activities in my lessons for the students, also improving and advancing my own professionalism."

Section 4: Effects and Benefits

This section describes the potential impact of Internet-based activities such as those described in Section 3. Beginning with the results of our questionnaire, a full two thirds of respondents thought that a primary benefit of the Internet is that it makes students aware that they are part of a global community. One said that "one reads about the global community, but the Internet enables them to walk the walk, not just talk the talk." The next most common answer was that the Internet "gives students a wide variety of resources." Respondents also thought that the Internet stimulates thinking, and that it improves computer literacy.

From our direct observations in a Pittsburgh elementary school classroom, it appears that an important benefit of using this technology is the tremendous enthusiasm it engenders in both students and teachers. Whenever the Internet teacher walked into the room, students appeared very excited and hopeful that it would be their turn to use the Internet. At one point, one student complained "Hey, why do they get to play on the computer?" Teachers even threatened to revoke a student's computer privileges as a punishment for disruptive behavior. Its hard to imagine a text book that could garner the same student response. As for the teachers, although such a project might tend to draw teachers that are naturally more enthusiastic than average, enthusiasm was obvious in both direct interviews and questionnaire responses. As one teacher wrote, "the possibilities are limitless."

The effects of the Internet and other information technology in the classroom are more complex than simply boosting enthusiasm or expanding information resources. The roles of teachers and students are fundamentally altered. First, consider a traditional classroom. The teacher is the principal source of information, the sole judge of good or bad work, and the authority who sets the pace of the course. The students learn in lockstep but with little collaboration allowed, interacting principally with the teacher. This is an appropriate model when the dominant instructional tool is the blackboard, but not when it is the Internet, as can be seen from the activities described in Section 3. When students write to impress a penpal or remote expert, the teacher is no longer the sole judge of quality, and grades are less of a motivating factor. Since there may be many experts on the Internet, the teacher is no longer the only authority. Students have many newfound opportunities to collaborate both with students in their own classroom, and with students far away. (Many activities require students to work in teams; equipment is often limited, and working in teams makes it less likely that progress will be halted, even when a technical problem is encountered.) When students spend class time browsing the Internet rather than listening to a teacher's lecture, students have to work more independently, and at their own pace. The increased independence of students was particularly obvious from our classroom observations when problems occurred. During initial training, students tended to direct questions to teachers, but once regular usage began, students were more likely to consult their peers. Throughout this process, the teacher becomes more of a facilitator, helping students find information, and more importantly, figuring out what to do with it. The latter skills are invaluable for students - more so than any fact they could learn. One teacher who uses the

Internet responded to our questionnaire that "I have changed them (teaching styles) to accommodate students' need for more experience with higher order thinking skills. They (students) need to be guided into analyzing and evaluating information much more than in the past."

There is also potential to change the role of parents with this technology in several ways. For example, during parents' nights, students may be able to teach their parents something new about computers or networks, which can greatly boost a student's self-esteem. Since familiarity with information technology can lead to jobs, schools may also want to make a more serious effort at training neighborhood adults after school hours. When parents have access to this technology at home or work, there is also great potential to involve parents more closely in their children's education. This may be closer to reality than it appears. Many parents already have Internet access at work. 35% of U.S. households now have computers, and households with children are more likely to have computers than those without, even households on a somewhat limited budget. 30% of households with children and total annual incomes under $30,000 have computers. Given that consumer spending on home computers now exceeds spending on televisions, these percentages should continue to rise quickly (Negroponte 1995). All it takes is a telephone line and a modem to connect a home computer to the network. More importantly, since there will always be parents without home computers, some states and municipalities such as Seattle are bringing network capabilities to all of their citizens. In Seattle, even the homeless will be able to communicate over the network by getting an account from the city, and using it in libraries and other public buildings.

Section 5: Overcoming Difficulties

Introducing the Internet in a K-12 curriculum is not always an easy task. In this section, we first present some techniques that our questionnaire respondents found to overcome difficulties. We then present more persistent problems reported by teachers. Finally, we describe a problem that no respondent raised, but that could prove dangerous: the availability of potentially objectionable material.

Below are the four most common suggestions from questionnaire respondents. First, teachers should be specific about expectations and objectives. They should also provide deadlines for the activity, and for intermediate milestones, to keep students moving in the right direction. Second, teachers should search the Internet themselves before asking students to do the same. As one said, "know what to look for in advance, so you and your parties (students) will not be disappointed." The third guideline is to allow ample time. One respondent said that you should "realize it will take twice as much time as you have budgeted." Another suggested that students work in groups to speed up the process. Finally, respondents recommended establishing a firm relationship with other parties involved in an activity. "Ensure that all participants are 100% into the activity. There is nothing worse than getting a project organized or planning a project into your lesson plans and then ... no mail from your partners or people start dropping out."

Questionnaire respondents identified three principal difficulties that were not entirely within their control: class duration, limited access to the Internet, and time. Beginning with the former, it is sometimes difficult for students to engage in an unstructured activity when class duration is

limited to 40 or 50 minutes. Allowing time for longer activities may require creative structuring of the school day. Second, some teachers had to overcome a lack of hardware, telephone lines, or accounts. In some cases, entire classes share a single account. Finally, lack of time was a problem. No good teacher ever has enough time to do all he or she would like to prepare for a class. However, the Internet provides additional challenges. Internet resources are vast, and the tools change from year to year. Keeping up is not easy. It will help when principals and others understand the value of the Internet, and the importance of teacher time spent working on it.

Probably the most disturbing problem was reported in direct interviews with teachers (that are not part of the Pittsburgh project). Not only are rewards for innovative teachers often small, but some teachers are actually discouraged by principals and/or fellow teachers from disrupting the status quo by adopting such technology. The reasons for such opposition may include fear that benefits will be small and not worth the effort, and fear that benefits will be great, so other teachers will be expected to keep up with their innovative colleagues. Providing proper teacher incentives for innovation is critical, and may require some fundamental changes.

Another problem with the potential to seriously disrupt an effort to bring the Internet to the classroom was not mentioned by any of our respondents, which is in itself a concern. The Internet gives students access to a vast array of information. A student using the Internet, like a student wandering the library of congress, may look at something her parents would prefer she not see. The most obvious example is sexually explicit material. Other topics may also stir controversy, such as drugs, politics, religion, abortion, and homosexuality.

Policy-makers are now attempting to address a part of this problem. In June of 1995, the U.S. Senate passed a bill that would prohibit the flow of "indecent" materiel (which is not limited to pornographic material) on the Internet. Aside from the serious civil rights implications of such censorship, it will not even prevent the distribution of pornography on this network with millions of users around the world, any one of whom can provide such information. The Washington State legislature found a more complete solution; they made it illegal to give minors Internet access, so minors will be protected from objectionable material. (The solution could be even more effective if minors were prohibited from learning to read.) The governor vetoed the bill.

There are a few precautions one can take, like not carrying some obviously troublesome newsgroups on local servers, and new information- filtering tools are coming. However, there is really no way to prevent a bright and determined student from finding something she wants to see. Constant teacher supervision is one solution, but it is difficult, time- consuming, and would deter curious exploration. The best approach is to develop a written policy stating what does and does not constitute acceptable student usage of the Internet. In general, Internet usage should relate to course work. Both students and parents must understand and agree to this policy before gaining access. This does not prevent abuse, but it does make it easier to revoke the privileges of students who violate the policy and it brings parents into the discussion from the beginning. (CMU 1994) contains examples of Acceptable Use Policies from several schools.

Section 6: Teacher Preparation and Support

A school system must determine how much preparation it will provide educators before adopting the Internet, and how much ongoing support to provide afterwards. At the moment, it appears that educators are typically provided little preparation. Two thirds of the respondents to our questionnaire had no formal training, relying instead on printed literature and experimentation, or as one person described it, "blood, sweat, and tears." If any thing, our methodology of distributing the questionnaires is more likely to overestimate the number of teachers with training. Thus, it is clear that preparation for educators is not essential, but it may still be helpful. Common Knowledge Pittsburgh has developed a professional development workshop for teachers and librarians that participants generally saw as quite successful. It is therefore worth describing here. The primary goal of the workshop organizers was to give participants the general problem-solving skills to become explorers of the Internet, rather than teaching them facts or rote methods. The Internet tools and resources are constantly expanding and changing rapidly. Teachers must have the ability to adapt. This view was independently echoed by several respondents to our questionnaire.

The workshop began in June. Participants received 13 hours of Internet instruction over a 2.5 day period. They worked in pairs to promote brainstorming, and to make the task less intimidating. Participants used a variety of tools ranging from newsgroups to gopher, and explored resources that workshop organizers thought might be useful, like the NASA library described in Section 2. This session concluded with a scavenger hunt for information on the Internet, where participants could test their newfound skills. After this 2.5 day session, participants borrowed school computer equipment and set it up in their own homes with help from the workshop organizers. Participants also took a manual home with them. This gave participants the opportunity to explore and experiment as much as they wanted at their leisure during the summer. It was an essential part of the learning process. Finally, the workshop formally reconvened in August for 10 hours of instruction over a two day period. This was a continuation of instruction, not a refresher. In addition to learning more about the Internet, participants discussed possible lesson plans involving the Internet.

We surveyed 14 of the participants in this workshop, and the responses were generally positive. Every participant agreed that the teaching methods were effective and only 7% did not yet feel capable of teaching the Internet to students, with 14% unsure. All participants found the workshop informative and almost all would recommend it to a colleague.

Since a primary goal of this workshop was to facilitate and encourage exploration, that issue deserves special consideration. Only 14% of participants indicated they were no longer exploring the Internet as of a couple months into the school year. 42% had done three or more new gopher searches in the week they were surveyed. Despite the popularity of the workshop, participants indicated that they learned only about half of the information on the Internet from the workshop instructors. That would also seem to corroborate the importance of independent exploration.

Participants did have some ideas on how the workshop could be improved. They were roughly evenly split on whether more step-by-step instruction time would help, but there was significant

demand for even more exploration time. There was also evidence that the manual provided was not as useful as it could be. An effective manual is a valuable asset.

Since one can't afford to stop learning about the Internet, ongoing support may also be important. Questionnaire respondents indicated that Internet guides, newsgroups, and distribution lists were very helpful. Personal support is also needed at times. Pittsburgh teachers turned to their fellow teachers most often, with the centralized support staff a close second. This is important because wide-scale adoption is only possible if teachers help each other; a centralized support staff can't be everywhere. When teachers do have questions for the central staff, none required a response within the hour, but 29% wanted a response within 1-4 hours, and another 57% within a day, according to our survey. When asked what other kinds of ongoing technical assistance teachers would like, the most common answers were classroom visits by Internet instructors, monthly meetings of Internet users, and on-line support.

Section 7: The Future

We have seen that more and more schools are gaining access to the Internet, and a number of creative and dedicated educators are integrating this technology into a K-12 curriculum. In this section, we consider the future of network technology in the schools, beginning with the technology itself. Teachers have only begun to exploit existing capabilities. Indeed, the majority of classroom activities that we have observed only use Internet tools that are more than two decades old: email, newsgroups, file transfer, telnet, and distribution lists. As described in Section 2, there are important newer tools such as Mosaic that greatly facilitate the process of finding information on the Internet. People are also experimenting with more interactive applications. For example, the Internet has been used for person-to-person video teleconferences, and to broadcast part of a Rolling Stones concert live. Moreover, the Internet is not the only network of importance. New networks are coming based on ATM (asynchronous transfer mode) technology, which will be better able to support high- bandwidth applications and to efficiently carry a diverse mix of traffic types including voice, video, file transfers, email, etc. For example, North Carolina has recently deployed a statewide ATM network, and schools will have access. The explosion in wireless networks also offers important new opportunities for educational use. Researchers here at Carnegie Mellon University and elsewhere are interested in finding ways to exploit these evolving technologies for K-12 education.

Although the growth of Internet usage in the schools is encouraging, the schools have not been keeping up with any of the commercial sectors in adopting new information technology, so it is not clear whether technical advances alone will be beneficial. There must be other obstacles. An obvious culprit is money. However, 97.2% of American schools already have some computers (Wheland 1995), and adding a low-speed Internet connection is no more expensive than adding a telephone line. Still, many of these computers are not integrated into the curriculum in a meaningful way, other than one designed specifically to teach about computers. While funding is certainly an issue, and more conclusive proof is needed that money spent on Internet access is more beneficial than money spent elsewhere, increased funding alone is unlikely to lead to productive use of information technology.

To truly exploit these advances, technology, and more generally innovation, must permeate the culture of education. Teachers should be exposed to technology early in their careers, and should be actively encouraged to keep up on its continual advances. New schools should be wired for computers and networks when they are built to reduce installation costs, just as commercial office spaces are. School districts should hire staff who can help schools build and troubleshoot computer and network systems. Teachers must be given license, and encouragement, to experiment with technology. Pittsburgh is showing that more teachers will choose to bring technology into the classroom when given both resources and encouragement.

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