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THE NETWORK CLASSROOM

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ABSTRACT

This paper discusses the role of the new computer communications technologies in education, specifically addressing (1) modern networking systems, (2) strategies for implementing network-based communications, and (3) public online information resources for the classroom.

INTRODUCTION

Historically, computers have been located in laboratories and used as teaching aids in science curriculums. Computers can also be used as a communications tool and in this capacity are appropriate for a variety of instructional applications. Public online information resources are available for most disciplines. Network-based services offer a unique opportunity. Previous instructional innovations were implemented as trial or pilot projects and treated as a supplement to the curriculum. Network- based instructional applications can be implemented within an institution's existing information infrastructure and treated as a core communications component supporting existing academic programs.

The implementation of advanced networking technologies through a system-wide evolution from existing computer technologies is timely since network technologies have been steadily decreasing in cost and the public network has been steadily increasing in reach and capacity. The interconnection of laboratories into the public internet is now feasible for most institutions. Following is a discussion of factors pertinent to the implementation of classroom-based network and internet technology including some suggestions for the use of public online resources in instructional settings.

COMPUTER COMMUNICATIONS

Networking is not so much a technology as it is a sociology--a means to communicate and share ideas (Edelhart; 1987; Thachenkary, 1987). Applications may range from simple classroom support via electronic mail and bulletin boards; to elaborate conferencing systems featuring pictorial displays of class members and intensive interpersonal interaction (RTZ, 1992); to online universities which use computer communications as a primary means of information delivery (Berlfein, 1991). A heightened capacity for student interaction and collaboration across multiple networks is one of the medium's most remarkable and unique contributions to education (Davie & Wells, 1991). Networks will increasingly seem 'transparent' as intelligent search and retrieval mechanisms gather, manipulate, process, and automatically present data from natural language queries (Rockart & Short, 1989).

The evolution into desktop workstations and network computing enables students to connect to national networks and receive a full range of online services. For example, instructors may use the Internet to develop curriculums which regularly feature input from dynamic information resources (Maule, 1992a). The systems may integrate public and private telecommunication services and incorporate industrial laboratory simulations while providing real-time monitoring and control of the network and all its resources. Online services will accommodate on-demand bandwidth for sophisticated applications including simultaneous video conferencing, collaborative computing, and Internet information access.

THE NEW NETWORK TECHNOLOGIES

A communications 'infrastructure' is composed of both technical and information resources and can support classroom instruction and laboratory experiments. Network 'utilities' can help to manage computer-assisted instruction at the local level and wide-area information services at the regional level while providing simultaneous interpersonal and group interaction.

LOCAL COMMUNICATIONS

Local-area networks turn personal computers into powerful multi-user machines capable of sharing information, enhancing personal communications, and providing new ways to collaborate. Current client/server LAN technology uses a central computer or server as the network host for programs, information, and internal and external communications (Elbert, 1992). New personal computer operating systems feature peer-to-peer networking--eliminating reliance on a dedicated server and greatly enhancing capacities for interpersonal communications.

The most interesting forms of computing generally use multimedia, which refers to computer communications which use video, audio, and animation. Multimedia must be supported by both hardware and software. The demand for multimedia is currently stimulating advances in both local-area network and wide-area network technologies and services with a wide variety of potential applications in education (Maule, 1992b).

Shared work spaces within computer-mediated environments and software supported group collaboration are newer additions to multimedia computing but will soon be standard (Anis, 1992). It is the capacity for multimedia group interaction, shared work spaces, and collaborative computing which further differentiate the new network-based instructional systems from previous educational innovations.

DISTANCE COMMUNICATIONS

A classroom or laboratory supported by a local area network is capable of resource sharing for participants at a single location. A current concern in business and industry involves cooperative computing across an enterprise, generally spanning many geographic areas, to enable remote team members to interact through the networks and thereby alleviate travel expenses and project delays. Education can model collaborative systems by making instructional computing assignments dependent on peer interactions via the networks.

Local-area networks may be interconnected to form metropolitan-area networks using phone lines, leased data lines, or proprietary cabling. Wide-area communications may be achieved through a proprietary enterprise network, through the public infrastructure, or through value-added services from private companies. A school district or university may choose to interconnect the campus LANs using a proprietary wide-area network (via leased lines or private cabling), and then interconnect this proprietary wide-area network into the public wide-area network; or each individual LAN could be connected into the public network and LAN-to-LAN communications established within the public network; or, a mix between these two extremes.

Cost will depend on the distance between the campus LANs, the proximity of the public network, the degree of interactivity, and the types of media being communicated. Ideally, instructors will be briefed in the overall potential of the technology, and the cost-benefit tradeoffs, and will adequately define their desired communication and information services. Multimedia, simulation, and group collaboration across the local or wide- area network can be satisfied using a number of technologies.

SIMPLIFIED TELECOMMUNICATIONS STRATEGY

The connection of the local-area network into the wide-area network, or internet, may be established as a voice-data public telephony service, a data communications technology, or a mix of public and private services (Casner & Deering, 1992; Heldman, 1992). A quandary arises when choosing wide-area network services for the transfer of graphics, pictures, audio, and full motion video. FDDI, ISDN, frame relay, SMDS, and ATM are all relatively new LAN interconnection technologies appropriate for interconnecting classrooms and viable for wide-area networks (Cerf, 1991; Lippis & Herman, 1991;

Pentland, 1992; Williamson & Tisch, 1992). The underlying assumption is that X.25 and dial- up communications are too slow to meet the needs of today's internets-- especially with the rapid evolution into multimedia computing.

FDDI

The fiber distributed data interface (FDDI) operates at 100Mbps (megabytes per second) and has been implemented as an upgrade for campus ethernet or token-ring LANs which operate at 10Mbps and 16Mbps respectively. FDDI is a local or campus technology capable of carrying interactive multimedia within that environment. It is a proprietary technology so the user must install and manage the media similar to ethernet or token-ring. FDDI-II operates at 600Mbps and was conceived as a campus and metropolitan area LAN interconnection system supporting data, high fidelity audio, and full motion video. Recent advances in competing technologies have cast doubt on the future of FDDI-II for metropolitan-area communications.

ISDN

The Integrated Services Digital Network (ISDN) is both a consumer and commercial integrated voice and data service viable for school, home, and business communications (McQuillan, 1992). Voice and data each have a separate channel. It is offered as a residential service with two 64Kbps (Kilobytes per second) channels (1 voice, 1 data) and one 16Kbps channel (packet data) and priced comparable to existing residential telephone services. Thus, ISDN is more powerful and less expensive than existing low capacity intra-city networks such as switched 56Kbps. Higher speed communications can be accommodated using Tprimary rate ISDN which offers speeds of 1.54Mbps. National ISDN will eventually link interexchange carriers to provide access to multiple switched services over a single circuit including digital dial- up, X.25, and Frame Relay (Aloia, Fitzgerald, & Kaufman, 1992).

FRAME RELAY

Of the new wide-area data services, Frame Relay is presently receiving considerable attention. It is a fast- packet technology and at 1.5Mbps is a substantial improvement over X.25 packet networks which typically operate at speeds between 9600bps and 56Kbps (Lippis & Herman, 1991). The transmission method has also been improved to further enhance network efficiency. Frame Relay has been demonstrated transmitting full motion video. Frame Relay is provided by the long distance carriers and value- added networks so it is a contracted service. Frame Relay is the immediate heir to X.25 for wide-area network communications.

SMDS

Switched Multimegabit Data Service (SMDS) is a LAN interconnection service offered by local telephone companies. It is a service, rather than a technology, so SMDS capacities and capabilities will be continuously expanding. The service is presently offered at rates from 1.5Mbps-34Mbps depending on whether a user contracts for DS-1 or DS-3 leased lines to connect the LAN into the SMDS (Travis, 1992). SMDS was envisioned as a metropolitan-area communications system to provide transparent

LAN-to-LAN interconnection, but recent demonstrations have suggested that SMDS will soon be a viable option for intra- and inter- state communications.

ATM

Perhaps one of the more intriguing new technologies is called Asynchronous Transfer Mode (ATM). It is concurrently a local-area and wide-area network technology, and both a computer and telecommunications technology. For computer users, ATM is a high speed local-area network switch. For the telecommunications industry, it is a high speed, multipurpose switch capable of routing traffic at 45Mbps-1.26Gbps (gigabyes per second) for Synchronous Optical Network (SONET) communications between telephone company central office switches. ATM is a proprietary technology at the local level and a contracted service at the national level. Thus, ATM offers a unique opportunity to integrate a variety of media and transmission formats. The full potential of distributed multimedia applications will be achieved through ATM, broadband ISDN, the Synchronous Optical Network (SONET), and software which supports collaborative work (Doll, 1992; Hoshi, Takahashi, & Mori, 1992).

SUMMARY

Public wide-area network technologies offer a substantial cost savings if connecting multiple remote locations. If the LANs are located within a campus environment, and instructors need multimedia communications between those LANs, then the most cost-effective solution is to interconnect those locations using fiber, coaxial, or twisted pair cable and implement FDDI. The FDDI network can then be connected into the public wide-area network or Internet. However, if the campus LANs are quite remote, and number more than a few, then one of the public network services (ISDN, Frame Relay, SMDS, ATM) would be more economical than leasing lines to interconnect the locations.

Using the public infrastructure, lines need only be leased into the closest network node for full interoperability among all LANs on the network. The Regional Bell Operating Companies, long distance carriers, cable television companies, value-added networks, and the telecommunications bypass operators all provide communications technologies in configurations likely to satisfy wide-area multimedia requirements.

NETWORKING STRATEGY

Application programs can automatically control switching operations, even for full motion interactive video, with simultaneous sessions, in multiple locations. The net effect is a wide-area network with the same communication and media processing capabilities enjoyed on the local-area network. The programs also provide bandwidth on-demand, sometimes referred to as dynamic bandwidth allocation, to dramatically reduce information processing and communication costs.

VIRTUAL SERVICES

New public network services enable users to configure the wide-area networks to achieve bandwidth on-demand. For instance, a video conference will require more bandwidth than a group cooperative

project. Similarly, collaborative applications require more bandwidth than text transfers. 'Virtual' network services automatically allocate bandwidth to help make network management transparent to users (Bessey, 1992). And, the user is only billed for the needed bandwidth. Thus, a classroom instructor can establish network projects based on information budgets available to a particular group.

The capacity to control networks and bandwidth has far- reaching implications. Control of the bandwidth (information conduit) will allow rapid calculation of infrastructure-based information costs and aid system managers who can then barter for competitive bids from the various suppliers--potentially treating bandwidth the way a utility treats energy sources, converting back and forth between sources and supplies depending on what is cheapest at the time (Anderson, 1992).

INFRASTRUCTURE SERVICES

The combination of text, images, sound, color animation, and full-motion video will transform networks of desktop machines into distributed workspaces ideally suited to collaborative projects (McQuillan, 1992). The communications infrastructure will support multimedia information to enable students to interact with rich intellectual resources, including distant teachers, libraries, and museums (Kay, 1991). The technology will extend to education and training resources such as desktop videoconferencing, multimedia database access, groupware and collaborative computing, and wide-area information services (Doll, 1992). Residential telecommunications services, such as ISDN, will enable students to access network resources from home through calls into the school LAN and participate in multi-party videoconferencing (Bajarin, 1992).

Using network management software, instructors can monitor and control activities on both the local LAN and on the wide- area network. Technologies such as ATM will enable instructors and students to define hardware and software- based applications and to create personalized services (Dunning, 1992; Sekimoto, 1992; Smyth, 1992). Thus, the infrastructure, rather than being a system that supports other services, becomes a programmable intelligence that can be distributed, managed and reconfigured by the user (Mulgan, 1991).

INSTRUCTIONAL STRATEGY

Of course, an advantage of computer supported instruction is that users may access resources at their convenience, complete exercises, respond to questions, and customize their learning to meet individual needs (Gooler, 1987; Hayes, 1989; Moore, 1990). However, one-to-one counseling, conferencing, group collaboration, and other forms of social interaction are crucial to the learning process (Knapper, 1988; Winkler, 1992) and can also be accommodated through network-supported instruction.

Users can interact within shared information workspaces. They may experience a greater quantity and a greater quality of information as users simultaneously share experiences and resources. The cumulative effect may be to produce new and different approaches to learning as participants serve as both teachers and learners in partnership with other learners (Duning, 1990; Riel & Levin, 1990). This

interactive, sharing process may occur at school, work, or home--complete with laboratory simulations, online conferencing, and collaborative computing.

NETWORK LABORATORIES

Interactive multimedia documents, self-contained hypermedia instructional programs, and computer simulations enable students to engage in exploratory learning and master difficult concepts on their own terms and at their own pace. Simulations require a structured media environment which supports the simulation (van Joolingen & de Jong, 1992). Multimedia communications aid this learning process since people learn more, and more rapidly, when they can see and hear while practicing new concepts (Hamilton, Smith, McWilliams, Schwartz, & Carey, 1992).

Multimedia instructional systems can be implemented as stand-alone applications or as a network-based resources integrated into computer-mediated communications (Maule, 1992b). Learning systems can integrate voice and image conferencing within laboratory simulations for online group projects. Online multimedia laboratory simulations with conference support will require both advanced telecommunications technologies (discussed above) and sophisticated network management tools.

NETWORK MANAGEMENT

Future learning systems will use advanced telecommunications switching equipment, a variety of interoperable networking technologies, and a mix of public and private telephony, network, and information services (Heldman, 1992). New tools place network control in the hands of instructors, enabling them to program both telecommunications and wide-area network services (Jackman & Lee, 1992; Lippis, 1992). From their desktop, instructors can monitor data hubs, information servers, bridges, routers, and clients (McBride & Brown, 1991). Network software is usually X-Window technology featuring graphical interfaces, network maps, point-and-shoot commands, and color-coded icons for ease-of-operation.

Instructors can monitor laboratory simulations, oversee network resources, and use simulations which span networks and operating systems while retaining full collaborative and conference capabilities. Instructors can dynamically initiate and guide student projects as groupware applications internetwork students on distributed LANs allowing them to work, share information, conduct conferences, and dynamically access information from distributed data bases, electronic bulletin boards, and other network resources (Edwards, 1992). Popular network-based applications will feature a shared workspace with participants simultaneously annotating and altering memos, diagrams, spreadsheets, graphs, and other documents--all while conducting a conference featuring audio and short video segments sent interactively or through electronic mail (McQuillan, 1992).

INFORMATION STRATEGIES

Public online information services provide various methods for searching, retrieving, and disseminating media using the networks. Bitnet (CREN), Internet, and Usenet are the major public networks.

Information access and media processing are aided by network software programs and information processing utilities. Network information servers available free and for public use contain comments and articles which may be posted on electronic bulletin boards, shared through Usenet newsgroups, distributed through Bitnet or Internet mailing lists, or stored as network files for anonymous file transfer (Johnson, 1992). Instructors can use network resources to supplement reading assignments, to stimulate student participation in conferences with peers around the world, or to assign network-based group simulations and collaborative projects.

INFORMATION UTILITIES

Several specialized application programs have been developed to serve as aids to access information from distributed, network- based resources (Tennant, Ober & Lipow, 1992; Johnson, 1992).

'Archie' is a program which helps users locate Internet information storage sites, and to identify media appropriate to specific needs and which is available for anonymous (free and public) download (Deutsch, 1992). 'Hytelnet' is a hypertext utility for locating Internet accessible libraries and public information services available for a remote login (Scott, 1992). Similarly, 'xLibrary' is a multi-tasking hypermedia network application, but one which also allows multiple network services to be active simultaneously. 'Wide-Area Information Servers' (WAIS) retrieve information from distributed databases, through a common interface, and are useful for keyword searching through large library collections across different Internet networks and computing platforms (Kahle, Morris, Davis, Tiene, Hart, & Palmer, 1992).

The Internet 'Gopher' is a popular network application for searching modular, distributed databases. It features a browsing tool and subject-oriented menus to search, retrieve, and display documents (Staff, 1992). Gopher servers have links to other Gopher servers, enabling users to move seamlessly and transparently from network to network, resource to resource. An even more sophisticated application is the 'World-Wide Web' which uses hypertext to organize and access resources from across the Internet (Berners-Lee, Cailliau, Groff, & Pollerman, 1992). It goes beyond Gopher and WAIS by providing pointers and chains within the text.

In a dynamic setting, users may combine network information processing utilities with online, interactive, multiuser communications to conduct conferences while simultaneously interacting with information resources throughout the world. Conference support can be added to network applications using the 'Internet Relay Chat' which is a multi-user, distributed, multi- platform, client/server software system which allows Internet participants to perform real-time computer conferencing.

ELECTRONIC INFORMATION

Electronic distribution lists or 'listservs' enable instructors to automatically distribute information through the various networks comprising the Internet. Listservs also archive information for access through electronic mail commands making them a useful research resource. Comserve (@vm.its.rpi.edu or @rpitsvm.BITnet) is a comprehensive online system for the communications

disciplines offering listserv list services, access to professional journals, bibliographic reference databases, and academic courseware. The Coalition for Networked Information (cni.org) develops information on national telecommunications policy and is a useful resource for student research. As the name implies, NetTrain (from listserv@ubvm.ccbuff.edu) distributes the latest network training information. A comprehensive listing of electronic discussion groups is available via anonymous ftp from ksuvxa.kent.edu in library/acadlist.readme.

Electronic newsletters are also distributed through listservs. The National Science Foundation Network newsletter (Linkletter from merit.edu) keeps readers abreast of NSF sponsored Internet activities. The wide-area information servers (WAIS) newsletter (from think.com) discusses software for automated network information searching. There is also a growing trend toward the electronic distribution of trade and academic journals. Indexing and archival features eliminate tedious legwork for researchers and students.

As public domain journals become an established and accepted means of professional publishing, and as the journals are archived in databases compatible with wide-area searching systems, it is conceivable that researchers and students will be able to enter search commands to scan journals throughout the world, locate needed sources, and retrieve appropriate data. Prominent electronic journals appropriate for studies in communications related disciplines include 'Interpersonal Computing and Technology: An Electronic Journal for the 21st Century' (ipct-j@guvm.bitnet), 'The Online Journal of Distance Education and Communications' (uwavm.u.washington.edu), 'EJournal' (listserv@vacsc2.albany.edu), and the 'Electronic Journal of Communication' (comserve@vm.its.rpi.edu). A comprehensive directory of electronic journals can be obtained via anonymous ftp from ftp.eff.org in the pub/journals/ directory.

AUTOMATED LIBRARIES

Library services are some of the most popular Internet online resources. There are presently over 150 domestic and 120 international online library catalogs with access by subject, title, author, and in some cases, key word and full text search. European catalogs can be accessed through the National Science Foundation relay server (sun.nsfnet- relay.ac.uk) which provides access to the JANET information system of the Open University. The PACS-L (unmvm.bitnet) mailing list is library-based and provides the latest information on online public access catalogs or OPACs. Librarians have been a leading and driving force behind the development of Internet information resources. Two comprehensive listings of libraries with OPACS are available via anonymous ftp. These are Billy Barron's directory (ftp.unt.ed in the library/ directory); and Art St. George's (ariel.unm.edu in the library/directory).

GOVERNMENT SUPPORTED RESOURCES

US Government services are provided by the National Science Foundation (nis.nsf.net), the NSF Science & Technology Information System (stis.nsf.gov), the National Technical Information Service (osi.ncsi.nist.gov), NASA (spacelink.msfc.nasa.gov), and the Library of Congress (dra.com). These resources contain a wide variety of data useful for science studies.

The National Public Telecommunications Network established "free-nets" as comprehensive bulletin boards organized to resemble electronic cities--complete with a city hall, library, post office, hospital, and town hall. These systems are easy to maneuver, highly enjoyable to use, and a good resource for introducing students to online services. Two of the more popular free-nets are at Cleveland (cleveland.freenet.edu) and Case- Western (freenet-in-a.cwru.edu). Free-nets are also a useful method for organizing information and might be appropriate for use by educational institutions and community organizations.

DISCUSSION

The evolution to network-based information delivery seems a certainty. Infrastructure-based networking technologies are pervasive offering the opportunity to upgrade institution-wide operations and provide benefits to an entire population. Infrastructure development costs are offset by reduced operating expenses, which can also be amortized across participants including education, industry, business, and government.

Technology innovators have often established pilot systems using processes foreign to traditional classroom instruction and then imposed the technology on the teachers--with disastrous results (Maule, 1988). By contrast, the new network-based systems can be implemented as part of an institution's communications infrastructure. Thus, a recommended implementation strategy is to evolve enhanced services from the existing network and computer communications systems. Instructors should be involved at each stage of the upgrade to be sure the technology aids their instruction and that they are aware of system operations.

Infrastructure-based services also afford institutions the opportunity to strengthen inter-organizational communications and build ties between universities, local schools, and the community. The high cost of switching technology necessitates shared equipment costs which may serve to further stimulate partnerships among business, industry, government, and education.

Additional research may help to determine the proper mix of information within networked, multimedia environments; to ascertain the impact of network-based communications on traditional learning patterns; to determine information and design processes for the distribution of information to various home, work, and social environments; and to determine application designs to achieve specific learning outcomes.

CONCLUSION

Network-based learning technologies have been slow to evolve due to the unusual nature of developing infrastructure services. However, advanced communications technologies can greatly enhance instructional programs and are necessary to support future workers in a highly competitive, global economy.

Infrastructure-based services, wherein control and responsibility is diffused and embedded throughout the various networks, may be used to build curriculums which reflect the dynamic nature of today's

workplace. Instructional systems can immediately reflect changes in the global economy. Network tools will enable users to create collaboratively, to disseminate shared experiences, and to customize their learning environment to satisfy individual interests.

Instructors using networked communications and infrastructure resources benefit from the convenience of desktop communications and from the availability of mechanisms to guide and stimulate interaction among students. Students benefit from exposure to the wealth of knowledge available to them through the global information networks. The overall educational process benefits from the implementation of network resources which keep students abreast of the latest information in their field, and which help them to establish associations linking education to opportunities in industry, business, and government.

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