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THE FUTURE OF MEDICAL EDUCATION ON THE INTERNET

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There has been a rapid growth in the development of large repositories of medical information and knowledge on the Internet. The Internet provides a new vehicle to disseminate timely information to assist in medical education. For the user, however, it is often difficult to obtain concise information or to verify the accuracy of that information. Advancements in technology and the development of interactive web browsers will improve the efficiency and accuracy of information, retrieval, and education. These advances will result from improvements made to the software interface and network infrastructure. Increases in data transmission rates, and more powerful computer systems will allow for extended use of graphical, video, and audio media on browsers. Many of the websites and databases will become more interactive. New program modules are already available to automatically "push" information on to the user's computer. Additionally, rising concern about the misinformation in many databases will drive professional organizations and companies to find methods to validate their information. Advances in computer technology will result in the development of new methods and aids in medical education. Virtual educational environments, simulations, and medical home visitations using telemedicine will add to the tools available to educators at universities and medical schools. Course instruction on the Internet already has been started at many universities and will continue to expand. Educational software programs will be designed to interact with the student, asking questions, and determining courses of action. Even with all the advances in technology and information dissemination methods, direct interaction with patients will continue to be essential to complete a medical student's educational requirement. Additional research will be required to determine if computer-based education is an effective alternative to classroom instruction and if these educational strategies can modify behavioral attitudes.

Key Words: Medical education; Internet; Computers; Networks; Databases

INTRODUCTION

AS NEW INTERNET technology becomes incorporated in everyday life, so too will its use in education. Medical education has traditionally been accomplished through a series of didactic lectures followed by individual mentoring of a senior staff member, usually performed on real patients. The transition from book to patient, especially in an operating room setting, can be quite profound. The new medical professionals have less time to learn increased volumes of information. Advances in computer technology can provide new methods to improve the amount of quality information that the stu-

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dent can absorb and will allow for innovative ways to demonstrate new and experimental procedures in a virtual environment.

Looking back to the last century, one sees many parallels between the emergence of electricity and the recent boom of the Internet (1). Electricity, when first developed by Thomas Edison in 1879, was impractical and expensive. No homes were wired; candles and gas lighting were relatively cheap, and there were few products available that used electricity. Edison and his electric company spent many years wiring homes and businesses and sold the idea that electricity was cleaner and safer than gas. He also persuaded companies to produce products that would use his electricity. The development of consumer items such electric sweepers, electric heaters, toasters, and the refrigerator forced communities to connect all homes to electricity at an accelerated rate. By the 1940s, the majority of homes were routinely using electricity.

Like the popularization of electricity, the usefulness and popularity of the Internet will increase as products are developed that are used on a daily basis by the average consumer. This will stimulate more and more people to connect to the Internet. The technology will become less dependent on the individual hardware or software, and more content oriented (2). The technology is moving from a PC centric to a network centric environment (Figure 1). Information, in many forms, will become the "commodity" that the consumer will request. Advancements in computer hardware and software will expand the amount of information available for medical education and offer new methods of education through the integration of audio, video, and text.

Hardware

In 1965, Gordon Moore, cofounder of Intel, predicted that semiconductor density would double every 18 months. This has held true for over 30 years. As the semiconductor density increases so does its speed. Computers have become faster and cheaper and there is no slowdown in sight. The new Pentium and PowerPC computers currently have clock speeds of up to 400 MHz with 500–600 MHz chips in development. Faster video interfaces and network cards allow the users access to audio and video forms of information. Disk drives have become faster and cheaper. Most new computer systems are routinely sold with a minimum two GB disk drives. New, faster computers allow software developers to design more interactive and user friendly programs with excellent response times.

Software

As computer hardware has become faster and cheaper, the software programs have become larger and more sophisticated. Programs and operating systems are almost all designed using graphical users interfaces (GUI) that are "in theory" easier to operate. Operating systems such as Mac OS or Windows 98 allow for point and click operation. Software programs are more interactive and have started to use some expert systems technology to learn from individual users. Many of the new software developments are several layers below the level that is used by the operator and not immediately evident. Currently, most programs are accessed by either a keyboard or a keyboard in combination with a mouse. Use of voice recognition has progressed slowly, but will play a major role providing friendlier computer systems in the near future.

Connections

The "information superhighway" is the interconnection of networks through fiber optic or copper wires. Computers can be connected locally (intranet), or throughout the world (Internet). The Internet was developed 30 years ago by the military as a network of networks. In 1969 ARPANET was established by the Advanced Research Projects Agency of the United States Department of Defense and computers slowly started to connect. In 1982 there were about 10,000 hosts connected; by 1992 over one million

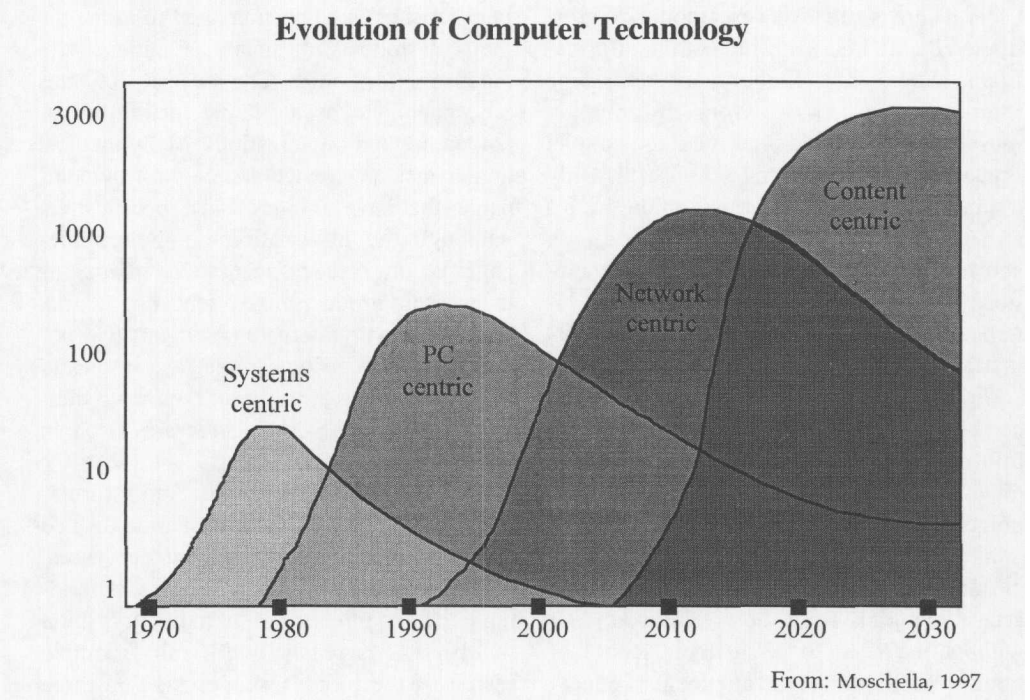

FIGURE 1. Evolution of Computer Technology: The first computers were large mainframe systems, inaccessible to most users. Remote 'dumb' terminals shared information and resources from a single central location (systems centric). With the development of the Apple Macintosh and IBM PC in the early 1980s, businesses started to purchase desktop computers for individual use. The computers had easy to use software, however, they required users to manually copy files on disk to transfer information from system to system (PC centric). Local area networks connecting office computers to each other, and the Internet, connecting networks together, has allowed users all over the world to share information. The transfer of information is becoming hardware independent (network centric era). Soon, many large information-based systems will allow for the access to this information from any interface box, at any location (content centric).

hosts were connected. To handle the increase in use of the network, InterNIC was created in 1993 by the National Science Foundation to administer the Internet backbone and was soon privatized in 1995. It is anticipated that 200 million computers will be connected by the year 2000 (3). Most individual users connect to the Internet using a modem at speeds of 28.8 Kbps whereas most businesses and schools have direct T1 connections to the Internet which is as much as 300 times faster than modem access. Increased access speeds of at least 4–6 Mbps are essential for computers to communicate with audio and video forms of information. New sites are growing at an exponential rate (4). Commercial domains have outpaced universities and governments. These connections allow communication between individuals, companies, and educational institutions. Commercial expansion of the Internet will increase competition for bandwidth, initially resulting in increased network traffic and slower responses. New types of Internet connections currently are being developed to increase bandwidth.

Information

The key to the future is information. The hardware, software, and connections provide the road. Where the road goes is up to the

users. There is already a vast amount of information on the Internet. Much of the information is either hard to find or inaccurate; some information is outright wrong. Information must be collected and presented in a simple, organized form in order to be useful. Only a minimal amount of information on the Internet today is approved or sanctioned by a sponsor. Institutions and medical associations will have to monitor and approve Internet sites to reduce the amount of misinformation.

Information can be in many forms, and can be accessed by several methods. Medical information on the Internet includes noninteractive materials such as electronic pamphlets, on-line references, and single page homepages. This information, while not new or innovative, is convenient. Students can access materials from their home computer without the need to go to their school or library. Similar to the development of educational materials on CD-ROM, information accessed from the Internet needs to be fast and interactive, using all forms of hypermedia (text, video, and audio) (5). One of the major advantages of having this information on the Internet rather than CD-ROM is the ease with which the hypermedia material can be easily updated.

Information can be more interactive when users communicate with other users. E-mail allows users to interact at their own schedule. Listservers are group mail programs that send mail to all persons who are interested in a topic and have previously signed up. Students then can get a census of options from cohorts in the field. Chat rooms allow for live interaction between users on-line. Most chat rooms are established for entertainment rather than for educational purposes. Validating users' identities is currently not available which is a problem and restricts the amount of medical information or advice provided over the Internet. Video conferencing between professionals has just begun in the university environment. It is only practical when the computers are connected to the Internet by high-speed T1 lines.

In the past two years, a large number of Internet sites have been created to assist the medical student, physician, or patient with medical information. The majority of sites are maintained by academic institutions or companies and organizations. Many medical homepages are created and paid for by companies that have an interest in a specific area. Although the information on their homepages is complete and accurate on treatments using their products, they tend not to link their pages with alternate treatments. Corporate sites are offering sample case studies to assist in the education about their drug therapy or product. Sample sites are listed in Table 1.

Search engines are used to find information on the Internet. The information located is dependent on the search engine that is used. As the volume of information increases, finding pertinent information in a timely fashion will become increasingly difficult. A simple search of the term "osteoporosis" on three separate Internet search engines yielded 32850 sites on Altavisa, 3405 on Lycos, and 47 on Yahoo. Clearly, the search criteria on Altavista were too lax and the list generated by Yahoo too limited. The development of "push" technology, or netcasting, allows the web browser to inform outside sites of the user's interests in a specific area and instructs these sites to automatically upload the information to the computer. The search engines or net browsers also need to have filtering options that can automatically remove unwanted or unnecessary data.

NEW ADVANCES

Telecommunications Convergence

Several advances in computer technology will change how medicine is taught in the near future. By the year 2002 most television broadcasts will be digital. A new digital TV standard has been adopted in 1997 which will require all TVs to have computer interfaces. Additionally, public radio transmissions also will slowly be converted to a digital signal. The computer/TV will have the new wide screen high definition TV format, increasing

TABLE 1
Some Internet Sites Demonstrating Various Methods of Dissemination of Information and Education.

Site Name	URL
Osteoporosis-related sites:	
Osteoporosis and Related Bone Diseases–National Resource Center	www.osteo.org/
National Osteoporosis Foundation	www.nof.org/
IFO–International Osteoporosis Foundation (formerly EFFO)	www.effo.org/
OSTEOVISION–An interactive information center in the bone field	www.osteovision.ch/
Osteoporosis Center–SUNY Stony Brook	www.informatics.sunysb.edu/internalmed/osteo/osteo.html
Osteoporosis guidelines–American Association of Clinical Endocrinology	www.aace.com/guidelines/osteoporosis.html
Osteoporsis Centre–Australia	www.sapmea.asn.au/qeh/ost_main.htm
Pharmacists Caring for Osteoporosis	www.uop.edu/pharmacy/asp/osteoporosis/osteo_home.htm
Osteoporosis–Doctor's Guide	www.pslgroup.com/osteoporosis.htm#Disease
Osteoporsis Online–Southeast Texas	www.ih2000.net/osteoporosis/
Priocal–Partners in the Nordic countries	www.priocal.se/
General Medical Education Sites:	
Med Nexus	www.mednexus.com/public/mnlinks1.html
Medsite	www.medsite.com/
Medweb–Emory University Health Sciences Center	www.cc.emory.edu/WHSCL/medweb.html#toc3
I-Med–the Internet Medicine Company	i-med.com/mdweb.html
NLM Resources and Distance Learning	wwwetb.nlm.nih.gov/workshop/Internet/
World Lecture Hall–University of Texas, Austin	www.utexas.edu/world/lecture/
Virtual Medicine Sites:	
The Virtual Hospital® The University of Iowa	vh.radiology.uiowa.edu/
Vancouver Hospital & Health Sciences Centre	www.vanhosp.bc.ca/
Global Health Network University of Pittsburgh	www.pitt.edu/home/ghnet/ghnet.html
The Interactive Patient–Marshall University School of Medicine	medicus.marshall.edu/mainmenu.htm

the picture size and quality. There will be increased competition between existing local TV and radio stations, cable companies, and new venture companies that plan to connect homes and businesses by a series of satellites. The telecommunications convergence will result in a single integrated device that merges the functions of telephone, computer, TV, stereo, and videoplayer. That device will directly access the Internet as needed to obtain requested information. Software programs and system upgrades will be available directly from the Internet. The device may or may not require a keyboard or mouse; instead it may use a remote control and voice recognition system to accept instructions.

Netsoftware Convergence

Web browsers and operating systems will become integrated into a single program. Users will be able to request information from outside their own computer while in a word processor. Programs will continue to become more interactive and contain audio and video formats. Expert systems, also called "artificial intelligence," will learn how users utilize a program and perform simple tasks automat-

ically. For example, each morning a user logs into the computer, reads E-mail, then searches the web for daily headlines on a particular topic. An active operating system could identify this pattern and automatically prompt the user to replay these sequence of events on subsequent days. Medical students as well as active healthcare providers can keep current on specific topics of interest. Additionally, the computer could routinely query the net, researching the specific topic, and informing the user when it found new articles. The "push" technology will become more prevalent and have options to filter out unwanted information.

Medical Information, Large Databases, and Data Repositories

The paperless patient medical chart will provide the patient and the clinician easy access to many forms of information including X-rays, CT scans, pathology slides, and other nontext forms of information. The patient information could reside on the hospital's mainframe computer or be downloaded to a credit card size "smart card." Patients could carry their "smart card" in their purses or wallets, allowing healthcare providers immediate access to their confidential medical files.

With expanded connections between users, companies, universities, and hospitals, very large databases can be designed to contain large volumes of information on specific disease processes (6,7,8). Large outcomes databases could be developed to share information about diseases and their treatment. Medical students with access to these databases could get a better understanding on how specific diseases and conditions are being treated not only at their own center, but at other institutions, internationally.

Communication

New technology will allow expanded communication between students, clinicians, and the public. E-mail has just started to be used to communicate between individuals. In the next several years teleconferencing and digital phone conversations will become more commonplace. Several of the large telephone companies are purchasing the technology to place phone calls over the Internet. The calls will be cheaper than conventional phone calls and not be restricted to any region. With increased bandwidth, audio and video could be sent with the same technology. Students with access to this technology could access established clinicians outside their own institution.

With the expansion of the Internet to audio and video transmissions, 'remote' or 'distant' education and telemedicine becomes more practical. There are already several universities offering virtual courses presented partially or entirely over the Internet. The lecturer is available to the student by E-mail. The major advantage of this form of education is that the student can access the course at his/her own time, independent of geographical location. Remote education also allows students to access live lectures from their computers. The professor broadcasts a lecture at a specific time and the student views the lecture at the same time as well as captures the lecture for review at a later time. Students from other programs also could have access to the information. Students can interact with the professor via E-mail, or by video/audio conferencing through a small camera on their computer. Teleconferencing is currently limited to a small number of users, but will expand as network speeds increase.

Telemedicine will allow physicians and students to consult with specialists at distant locations. Patient records, radiographs, scans, and video of dynamic procedures can be shared real time. This can bring state-of-the-art specialized care to remote locations.Currently, telemedicine equipment and procedures have been initially developed by the military and tested at several hospitals. At the Ohio State University, the University Medical Center is connected with several satellite sites, including some of the state prison facilities. Remote examination of prisoners has saved thousands of dollars by reducing the cost of transporting prisoners to the medi-

cal center. The first applications of telemedicine have already spread to the general population. Cardiac patients can call and transmit heart data collected from their pacemakers to their physicians. The physician can evaluate the health of the patient and determine if an in-house exam is warranted. As new devices designed to collect medical information on patients at home increases, use of the "virtual house call" will become more commonplace.

Virtual Reality Medicine

Presently, advanced medicine is largely taught by demonstration. A senior surgeon will show a resident a surgical procedure several times and eventually the resident performs that surgery on a patient under supervision. Virtual reality medicine will allow training of residents and other medical personnel on 'simulators' rather than on real patients. Similar to the flight simulator, surgery simulators will familiarize medical students and physicians with the feel of the instruments and the sequence of the surgery, and identify an area of difficulty during the course of the operation. The student can then review his/her procedure and the mentor can assess the student's performance. The exact same simulation could be used and repeated to compare performances of many students. Omission or substitution of components of a procedure could be programmed into the simulation to test students. Unusual events also can be programmed into the simulation to give the student experience in handling crisis situations. Books on surgical procedures will be updated or replaced with multimedia, interactive simulations, instructing the medical student on several different levels. Thus far, there have been several prototype systems developed by private industry and universities. Examples of medical simulations include administration of regional epidural analgesia (9), endoscopic sinus surgery (10), endoscopic retrograde cholangio-pancreatography (11), and arthroscopic knee surgery (12). A major factor slowing the advancement of virtual reality medicine is the cost of the computer hardware which can exceed $500,000 per simulator.

CONCLUSION

With all the advances in computer technology, some basic principles will not change. Patients want to be informed directly by their physician. Direct human interaction will never be completely eliminated by computers, especially in medicine. Hands on physical exams remain important in the diagnosis and treatment of the patient. Medical students will be taught with these methods by other physicians with the assistance of computers. The rate at which computers automate aspects of medical education will be dependent, in part, on the availability of funds for the production of 'state-of-the-art' medical educational technology. Additional research and experimentation are required to explore which educational programming techniques and technologies will be effective in efficiently educating future physicians and healthcare professionals.

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