Educational Applications of Computers in Medical Education

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Computers have been used in various aspects of medical education since the 1960s. Recent technological developments have resulted in an explosion of more powerful and economical computer hardware, which is now as easily available as television or stereo. In this article the use of computers in medical education will be explored by looking at past and present practices and problems. How computers will be used in medical education and the implication of their future use for medical students, residents, faculty, and practicing physicians will be examined.

The First 20 Years

Computers were recognized at an early stage in their development as a new technology to be exploited in medicine—particularly in medical education. The ability to manipulate large amounts of data provoked interest in computer applications for the management of educational activities and student assessment. Further interest was generated by the computer's potential role in determining the diagnosis and prognosis of disease and in developing therapeutic plans in patient care. Predictions were made that the available technology would save time, improve efficiency and skills, and provide unique learning opportunities.

Early efforts to apply computer science to medical education resulted in a number of interesting but limited projects. The computer of the 1960s was a large mainframe machine filled with vacuum tubes and miles of wire. Because of the great expense involved and the need for technical maintenance expertise, computers were located only in large business and governmental or educational centers. Computer applications during this time were largely industrial or military, although at least one large computer-based instruction project for postsecondary education, PLATO (Program Logic for Automatic Teaching Operations), was developed at the University of Illinois. PLATO is a large and expensive centralized computer system capable of storing great amounts of data and executing complex instructional strategies that are teacher centered and controlled. PLATO marked a successful application of computers to educa-

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tion, but was not widely adopted because of its expense.[1]

The next stage in this evolutionary process was the introduction of the minicomputer. Still relatively expensive, the minicomputer relied heavily on transistors for its internal operation, making it a much more compact unit than its predecessors. A large-scale computer-based instruction project, TICCIT (Time Shared Interactive Computer-Controlled Information Television), was developed using this new technology. TICCIT was totally learner centered and organized, using the computer and instructors as resources. Included in this instruction were some of the first computerized medical simulations for instruction.[1]

During the same period that TICCIT was being launched, a joint project was beginning to take shape between the National Board of Medical Examiners and the American Board of Internal Medicine. This project, the Computer-Based Examination Project,[2] sought to develop a computer-based system for evaluating clinical competence through the use of computer programs that simulated patient problems. Although the project has not yet been completed and implemented, it marks a major step forward in the use of computers in medical education.

Problems

Although all three of the projects mentioned are landmarks in the evolution of computers for use in instruction, widespread adoption of these computer-based instruction models has not occurred. According to Anastasio and Morgan[3] in a report written as early as 1972, a number of difficulties have presented roadblocks to wider use of computers in instruction:

> The complex factors inhibiting widespread use of computers in instruction have three principal dimensions—educational, economic, and technical. These three dimensions are reflected in the six categories . . . a) production and distribution of instructional materials; b) demonstration of the effectiveness of CAI (computer-assisted instruction); c) theory of instruction; d) educational system and the teacher; e) cost; and f) technical research and development.

Table 1 summarizes some of the problems identified from various sources in each of these six categories. As can be seen, developers were faced with many difficult problems.

Advent of the Microcomputer

Although educational problems with the first computer systems and computer-based instruction models could have been overcome with time, economic and technical difficulties presented the biggest challenge. Fortunately, a breakthrough in technology, the development of the microchip,[10] helped to reduce greatly the number of technical difficulties, and in time, mass production techniques helped to dissolve economic barriers.

This single technological development, the microchip, resulted in the production of much cheaper and more reliable computers of manageable size, which rapidly became available in schools, businesses, and homes across the country. Although several substantial problems in the use of computers in education were solved by this breakthrough, many still remained as major impediments to large-scale use.

A number of the problems enumerated in Table 1 persist. Production and distribution remain problems, as there are few tangible rewards for those who write computer programs. The development of new materials is not viewed with the same favor as research or traditional teaching activities. The considerable effort required to produce software materials is therefore confined to a few individuals who are able to see a potential profit or who have a special interest. As a result, the quality and quantity of materials are lacking. While fun to complete, most existing computer-assisted instruction programs or patient management problems are not challenging or flexible enough for most physicians.

The effectiveness of computer-assisted instruction has yet to be convincingly demonstrated, particularly in medical education. To add to the woes of computer-assisted instruction, the underlying instructional theory necessary to develop valid strategies is still poorly conceived. It is not difficult to see the role of the computer in the storage, retrieval, and manipulations of data that may be presented in a form assisting in the diagnostic,

Table 1. Problems of Educational Applications of Computers

Categories[3]	Problems (1955-1975)
Theory of instruction	Poor understanding of the computer's capabilities in education Information processing potential not reached
Education system and the teacher	Poor understanding of the role of the student and the teacher Perception of threat to job security Not well integrated into medical curriculum[4,5] Fear of new technology[4]
Demonstration of effectiveness	Only small positive effects realized for attitude and achievement[6,7] Few good examples available
Technical research and development	Reliability of equipment Difficult mode of input Languages difficult to use[8] Monosensory[9]
Production and distribution	Lack of faculty interest Dispersion of responsibility Lack of incentives Lack of good materials Lack of production methods
Cost	High cost of hardware and software[5]

prognostic, and therapeutic decision-making process. It is exceedingly difficult, however, to see how a new technology, which is perceived as a threat and is not well understood, can be of help in educational programs in which there is little teacher expertise. The potential offered by computers and their application to specific and appropriate areas of teaching is not well developed, thus limiting their usefulness.

Teachers in the public school system are rapidly adding computerized instruction and courses in computer literacy to the curriculum. Medical schools have been slower to adopt these new methods; consequently, entering students frequently are more familiar with computers and their uses than the faculty. The difficulty of gaining familiarity with new languages may also dull faculty interest.

The picture is not all bleak, however. Some initial problems have been wholly or partially solved. The microcomputer has made hardware cheaper, smaller, more reliable, and more widely distributed. Microcomputers have the advantage that programs on "diskette" may be readily distributed and exchanged, but they are limited in that, generally speaking, programs developed on one computer may not be easily used on others. The memory capacity of a modern microcomputer may also limit its use, although the development of hard disks and the availability of increasing memory capacity are changing this situation rapidly.

The sophistication of available programs may

not be great, but the number and variety of programs are increasing. Experience is accumulating and an improved product can be anticipated. These programs, however, do not currently offer flexibility for the learner by responding to his or her needs or learning style.

Current Educational Applications of Computers

Of the many computer uses currently being explored, the following categories summarize the major uses in medical education.

Learning

Many programs are now available on diskette. Most have been developed for Apple II or Apple IIe computers, which seem to be by far the most commonly found. The programs are often interesting and stimulating, but require the learner to follow a fixed tutorial direction without offering much flexibility. Several centers are working on the integration of videotape or videodisc materials, but these developments are still in their infancy.

A number of clinical simulations are available for use specifically on microcomputers. The simulations follow a format similar to that for programs developed for PLATO but remain relatively unresponsive to the needs of the individual student. Although capable of teaching and testing knowledge and clinical reasoning and demonstrating skills, such programs cannot test skills, performance, or attitude. Most of these programs use a linear format in which information is presented to the learner, and an understanding of the new information is immediately tested. Further help is offered where learning is deficient, and a summative test is offered at the end of the program. Most of the patient management problems follow the familiar linear design. Mainframe computer programs are able to offer more complex branched programs, but these are not yet available for use on microcomputers.

Clinical simulations are in the process of development for continuing medical education, where they hold some promise as a combined teaching and self-assessment tool.

Evaluation and Assessment

A number of programs developed around patient management problem models score the learner as the problem proceeds as a means of self-assessment. Cumulative scores may be registered on the diskette, and then may be available to both teacher and learner. Again, video applications are being developed, but these programs are not currently being used for evaluation or assessment.

One computer application that is available and does work well is the storage and retrieval of multiple-choice questions. Large numbers of multiple-choice questions may be stored easily on diskette and retrieved for an examination in a randomized fashion or as blocks of questions on specific topics.

Information Management

A successful use of computer technology in education is in conducting literature searches. Catalogues of published articles have been accessible by computer for several years. Two of the most familiar are MEDLINE and MEDLARS, both of which offer key word searches. MEDLARS also provides an annotated printout.

Computers may also be used in the organization and storage of large data bases for medical use. Programs such as AMA/NET (or Telenet) are being developed under which the vast volume of current medical information can be stored and retrieved for use in solving clinical problems.

Documentation of Learning Experiences

Many residency programs document the clinical experiences of their residents for educational purposes and to provide evidence for hospital privileges. Most such computer programs currently in use rely on information obtained from patient bill-

ing data. There is little consistency among programs and, as yet, no national agreement exists on what should be recorded or what constitutes the essential experiences that should occur during each resident's training.

The Future

Given the rate of change in computer technology in recent years, it is probable that many or most of the problems enumerated in Table 1 will be overcome. It seems likely, however, that progress will be slow as software is perfected, new skills are learned and disseminated, and educational theories are developed. Once these problems are surmounted, the impact of computers on medical education could bring about profound changes in the learning process for medical students, residents, and practicing physicians. Equally far-reaching are the effects that can be anticipated in the role of faculty and the institutions they serve.

Impact on the Learner

Perhaps one of the most obvious applications of computers in medical education—and one that is acutely needed—is data retrieval. The increase in information available to physicians has been exponential as research has advanced medical knowledge. Maintaining knowledge at a current level is a problem for all physicians and an even greater challenge to medical students, who have not yet developed a cognitive framework in which to integrate new information. Computers offer the potential for storage and retrieval of information that may be accumulated over time. Information may be stored in a way most compatible for the individual's learning and problem-solving style. Rote memorization of large quantities of facts will no longer be necessary, freeing physicians from this discipline and allowing more opportunities to focus on clinical reasoning and interpersonal skills.

As computer networking develops, it will become possible to revise and update a computerized data base from a central source. Advances in data storage and retrieval, coupled with a greater ease in assessment, will lead to the development of a more individualized curriculum that will allow students to progress quickly through areas already mastered or those found to be relatively easy. More time may be assigned to areas of weakness or special interest.

More interactive computer programs will allow flexibility not only for learning but also for testing and prescriptive feedback. Areas of weakness will be more easily identified, and specific remediation will be available with retesting until competence is achieved. Thus the curriculum is likely to be driven almost entirely by the needs of the individual, and the result may well be a profound change in the role of the faculty.

Impact on the Teacher and Teaching Program

The computer will be able to assemble and present information in a form designed to fit the needs of the individual learner, offering greater flexibility than current instructional methods. The need to impart large numbers of facts through a lecture or seminar is likely to diminish greatly. The teacher's role will therefore become that of a mentor, advising and guiding the student in the choice of a wide range of learning opportunities. It may be possible to teach physical examination skills through the use of computerized holograms or models, but it is unlikely that the computer will supplant the teacher as a clinical role model or personal advisor.

The development of more individualized learning will change medical school curricular and institutional structures. The admissions process will select students who are more self-directed. Curricula will become self-paced and competency based. Testing of carefully selected competencies will become a major preoccupation of the faculty, who will require demonstration of a comprehensive range of knowledge and skills to a required standard prior to graduation. The development of appropriate instructional assessment software will become a valued faculty activity and will require the nurturing and development of resource teams to aid in programming and implementation.

The student academic record is likely to become computerized and will be much more comprehensive than at present. An exposure to specific clinical situations and procedures will be required and monitored closely. Documentation of experiences in medical school will be linked to residency training, where such documentation is already assuming great importance.

Departments of medical education are likely to develop more expertise in individual learning styles, the teaching and assessment of clinical reasoning skills, and the identification, teaching, and assessment of fundamental history taking, physical examination, and interpersonal and procedural skills. The primary teaching and assessment tool will, of course, be the computer.

Impact on Medical Practice

The manipulation of huge numbers of medical facts will result in a greatly increased understanding of disease and health. The data base developed on computers in medical school will be refined, revised, and extended in practice, contributing to a higher standard of medical care, stimulating new strategies for problem solving, and allowing more time for a more personal approach to patients.

Licensing examinations will likely become competency based, dependent not on a specific period of training but on demonstrable performance at a specific level. Testing will continue until a satisfactory performance is obtained. Thus, highly competent students whose level of test performance is outstanding may receive a relatively short examination, whereas those whose performance is marginal could be tested at length to ensure that minimal competency levels have been reached.

Continuing medical education is likely to be conducted through computer terminals in the office or home. Programs will be increasingly sophisticated and more interactive and will provide constructive, prescriptive feedback, raising the possibility of continuing assessment of competency in practice through computerized testing. Certainly relicensure is likely to be conducted in this manner. Documentation of continuing competency will be important for renewing hospital privileges and perhaps for obtaining malpractice insurance.

Conclusions

The pace of technological change in the computer field over the past two decades has been breathtaking. It is tempting to predict that the computer promises to be a panacea for all educational ills. If the rate of progress in its development continues, it is unlikely problems that currently are impediments to the integration of computers in medical education will remain so. Technological advance, however, is rarely a complete answer in and of itself, since it demands an adaptation by affected individuals. Ultimately the success of computers in medical education will depend on their acceptance and integration by both learners and teachers. It is hard to imagine a complete rejection of this new and exciting educational tool, but it is equally difficult to predict to what extent it will receive acceptance and how the present educational system will adapt to its many uses. Clearly the personal relationship between teacher and student will remain a central element in the educational process, but that relationship is bound to change. It will be intriguing to watch its evolution.

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