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Computers in Medical Education

Parvati Dev, Edward P. Hoffer, and G. Octo Barnett

After reading this chapter, you should know the answers to these questions:

• What are the advantages of computer-aided instruction over traditional lecture-style instruction in medical education?
• What are the different learning methods that can be implemented in computer-based education?
• How can computer-based simulations supplement students’ exposure to clinical practice?
• What are the issues to be considered when developing computer-based educational programs?
• What are the significant barriers to widespread integration of computer-aided instruction into the medical curriculum?

21.1 The Role of Computers in Medical Education

The goals of medical education are to provide students and graduate clinicians specific facts and information, to teach strategies for applying this knowledge appropriately to the situations that arise in medical practice, and to encourage development of skills necessary to acquire new knowledge over a lifetime of practice. Students must learn about physiological processes and must understand the relationships between their observations and these underlying processes. They must learn to perform medical procedures, and they must understand the effects of different interventions on health outcomes. In addition, student must learn “softer” skills and knowledge, such as interpersonal and interviewing skills and the ethics of medical care. Medical school faculty employ a variety of strategies for teaching, ranging from the one-way, lecture-based transmission of information to the interactive, Socratic method of instruction. In general, we can view the teaching process as the presentation of a situation or a body of facts that contains the essential knowledge that students should learn; the explanations of what the important concepts and relationships are, how they can be derived, and why they are important; and the strategy for guiding interaction with a patient.

As has been discussed throughout this book, information technology is an increasingly important tool for accessing and managing medical information—both patient-specific and more general scientific knowledge. Medical educators are aware of the need for all medical students to learn to use information technology effectively. Computers also can play a direct role in the education process; students may interact
with educational computer programs to acquire factual information and to learn and practice problem-solving techniques. In addition, practicing physicians may use computers to expand and reinforce their professional skills throughout their careers. The application of computer technology to education is often referred to as computer-assisted learning, computer-based education (CBE), or computer-aided instruction (CAI).

In this chapter, we present basic concepts that people should consider when they plan the use of computers in medical education. We begin by reviewing the historical use of computers in medical education, describing various modes of computer-based teaching, and giving examples of teaching programs for preclinical students, clinical students, medical professionals, and the lay public. We then present questions and discuss methodologies to consider in the design and development of teaching programs. In closing, we describe evaluation studies that investigate how these programs are used, as well as the efficiency of CBE.

21.1.1 Advantages of Using Computers in Medical Education

A computer can be used to augment, enhance, or replace traditional teaching strategies to provide new methods of learning. With its vast storage capacity, a computer can be an extension of the student's memory, providing quick access to reference and new content. Multimedia capabilities allow the computer to present rapidly a much larger number of images than can be accessed through a book or an atlas and to supplement the static images with sounds, video clips, and interactive teaching modules. Immersive interfaces, which present three-dimensional worlds and allow touch and force feedback through a joystick or instrumented glove, promise to support the training environment of tomorrow.

A computer, properly used, can approach the Socratic ideal of a teacher sitting at one end of a log and a student at the other. In contrast to traditional fact-based, lecture-oriented, mass broadcasting of information, computers can support personalized one-on-one education, delivering material appropriate for learners' needs and interests. “Any time, any place, any pace” learning becomes practical. In traditional education, the learner goes to the lecture, which is held at a specific time and location. If it is not possible for the learner to attend the lecture, or if the location is difficult or expensive to reach, the potential experience may be lost. Computer-based learning can take place at the time and location best suited to the needs of the learner. It can also be individualized and interactive; the learner is able to proceed at his or her own pace, independent of the larger group. By placing the student in simulated clinical situations, or in a simulated examination, a computer-based teaching program can exercise the student’s knowledge and decision-making capabilities in a nonthreatening environment. Finally, well-constructed computer-based learning can be enjoyable and engaging, maintaining the interest of the student.

1Although the focus of this chapter is medical education, the underlying concepts and issues apply equally to nursing and health sciences education.
21.1.2 A Historical Look at the Use of Computers in Medical Education

Despite the many advantages, computer-assisted learning programs initially experienced slow growth before gaining acceptance. Piemme (1988) traced the early development of computer-assisted learning in medicine and discussed reasons for the slow acceptance of this technology. Today, computer-assisted learning has become widely available in the medical field.

Pioneering research in computer-assisted learning was conducted in the late 1960s at three primary locations in the United States: Ohio State University (OSU), Massachusetts General Hospital (MGH), and the University of Illinois. Earlier attempts to use computers in medical instruction were hindered by the difficulty of developing programs using low-level languages and the inconvenience and expense of running programs on batch-oriented mainframe computers. With the availability of time-sharing computers, these institutions were able to develop interactive programs that were accessible to users from terminals via telephone lines.

CBE research began at OSU in 1967 with the development of Tutorial Evaluation System (TES). TES programs typically posed true–false, multiple-choice, matching, or ranking questions and then immediately evaluated the student’s responses. The programs rewarded correct answers with positive feedback. Incorrect answers triggered corrective feedback, and, in some cases, students were given another opportunity to respond to the question. If a student was not doing well, the computer might suggest additional study assignments or direct the student to review related materials.

In 1969, TES was incorporated into the evolving Independent Study Program, an experimental program that covered the entire preclinical curriculum and was designed to teach basic medical science concepts to medical students (Weinberg, 1973). Although the program did not use CBE in a primary instructional role, students in the program relied heavily on a variety of self-study aids and used the computer intensively for self-evalution. The use of COURSEWRITER III, a high-level authoring language, facilitated rapid development of programs. By the mid-1970s, TES had a library of over 350 interactive hours worth of instructional programs.

Beginning in 1970, Barnett and coworkers at the MGH Laboratory of Computer Science developed CBE programs to simulate clinical encounters (Hoffer and Barnett, 1986). The most common simulations were case management programs that allowed students to formulate hypotheses, to decide which information to collect, to interpret data, and to practice problem-solving skills in diagnosis and therapy planning. By the mid-1970s, MGH had developed more than 30 case management simulations, including programs for evaluation of comatose patients, for workup of patients with abdominal pain, and for evaluation and therapy management in areas such as anemia, bleeding disorders, meningitis, dyspnea, secondary hypertension, thyroid disease, joint pain, and pediatric cough and fever.

The MGH laboratory also developed several programs that used mathematical or qualitative models to simulate underlying physiological processes and thus to simulate changes in patient state over time and in response to students’ therapeutic decisions. The first simulation modeled the effects of warfarin (an anticoagulant drug) and its effects
on blood clotting. The system challenged the user to maintain a therapeutic degree of anticoagulation by prescribing daily doses of warfarin to a patient who had a series of complications and who was taking medications that interacted with warfarin. Subsequently, researchers developed a more complex simulation model to emulate a diabetic patient's reaction to therapeutic interventions.

About the same time, Harless et al. (1971) at the University of Illinois were developing a system called Computer-Aided Simulation of the Clinical Encounter (CASE), which simulated clinical encounters between physician and patient. The computer assumed the role of a patient; the student, acting in the role of practicing physician, managed the patient's disease from onset of symptoms through final treatment. Initially, the computer presented a brief description of the patient, and then the student interacted with the program using natural-language queries and commands. The program was able to provide logical responses to most student requests. This feature added greatly to the realism of the interaction, and CASE programs were received enthusiastically by students. The TIME system, later developed by Harless et al. (1986) at the National Library of Medicine (NLM), extended CASE's approach to incorporate videodisk technology.

CBE programs proliferated on a variety of hardware, using a babel of languages. A 1974 survey of the status of medical CAI identified 362 programs written in 23 different computer languages, ranging from BASIC, FORTRAN, and MUMPS to COURSEWRITER III and Programmed Logic for Automated Teaching Operations (PLATO) (Brigham and Kamp, 1974). Little sharing of programs among institutions was possible because the task of transferring programs was typically as large as writing the material de novo. Thus, there was little opportunity to share the substantial costs of developing new CAI programs. The lack of portability of systems and the extreme expense of system development and testing served as barriers to the widespread use of CAI.

The establishment of an NLM-sponsored, nationwide network in 1972 was a significant event in the development of CBE in medicine because it allowed users throughout the country to access CBE programs easily and relatively inexpensively. Previously, the programs created at OSU, MGH, and the University of Illinois were available to users in selected regions over voice-grade telephone lines. Poor quality of transmission and high costs, however, combined to limit access to CBE programs by distant users. Acting on the recommendation of a committee of the Association of American Medical Colleges, the NLM's Lister Hill Center for Biomedical Communications funded an experimental CBE network. Beginning in July 1972, the CBE programs developed at the MGH, OSU, and the University of Illinois Medical College were made available from these institutions’ host computers over the NLM network. During the first 2 years of operation, 80 institutions used the programs of one of the three hosts. The high demand for network use prompted the NLM to institute an hourly usage charge, but use continued to rise. Having exhausted the funds set aside for this experiment, the NLM discontinued financial support for the network in 1975.

As a testimony to the value placed on the educational network by its users, MGH and OSU continued to operate the network as an entirely user-supported activity. Beginning in 1983, the MGH programs were offered as the continuing medical education (CME) component of the American Medical Association’s Medical Information Network (AMA/NET). AMA/NET provided a variety of services to subscribing physicians in
addition to the CME programs, including access to information databases, to the clinical and biomedical literature, to the DXplain diagnostic decision-support tool, and to electronic-mail services. By the mid-1980s, approximately 100,000 physicians, medical students, nurses, and other people had used the MGH CBE programs over a network, with about 150,000 total contact hours.

During the early 1970s, medical schools around the country began to conduct research in CBE. One of the most interesting programs was the PLATO system developed at the University of Illinois. PLATO used a unique plasma-display terminal that allowed presentation of text, graphics, and photographs, singly or in combination. An electrically excitable gas was used to brighten individual points on the screen selectively. The system also included TUTOR, an early authoring language, to facilitate program development. By 1981, authors had created 12,000 hours of instruction in 150 subject areas. The programs received heavy use at the University of Illinois; some of them also were used at other institutions that had access to the system. The high cost of PLATO and the need for specialized terminals and other computer hardware, however, limited the widespread dissemination of the system.

Research on medical applications of artificial intelligence (AI) stimulated the development of systems based on models of the clinical reasoning of experts. The explanations generated by computer-based consultation systems (e.g., why a particular diagnosis or course of management is recommended) can be used in computer-assisted learning to guide and evaluate students’ performance in running patient simulations. The GUIDON system was one of the most interesting examples of such an intelligent tutoring system. GUIDON used a set of teaching strategy rules, which interacted with an augmented set of diagnostic rules from the MYCIN expert system (see Chapter 20), to teach students about infectious diseases (Clancey, 1986).

Researchers at the University of Wisconsin applied a different approach to the simulation of clinical reasoning. Their system was used to assess the efficiency of a student’s workup by estimating the cost of the diagnostic evaluation (Friedman et al., 1978). In one of the few successful field studies that demonstrated the clinical significance of a simulated diagnosis problem, Friedman (1973) found significant levels of agreement between physicians’ performance on simulated cases and actual practice patterns.

As we discuss in Section 21.4, the development of personal computers (PCs), authoring systems, and network technology removed many of the barriers to program development and dissemination, and CBE software proliferated. PCs provide an affordable and relatively standard environment for development, and CBE programs are now widely available via Internet, CD-ROM, and other media. Section 21.3 describes just a few of the many CBE applications now available.

### 21.2 Modes of Computer-Based Learning

To practice medicine effectively, physicians must have rapid access to the contents of a large and complex medical knowledge base, and they must know how to apply these facts and heuristics to form diagnostic hypotheses and to plan and evaluate therapies. Thus, conveying a body of specific medical facts, teaching strategies for applying this information in medical practice situations, and assisting students in developing skills for
lifelong learning are among the goals of medical education. Computers can be used for a wide range of learning methods, from drilling students on a fixed curriculum to allowing students to explore a body of material using methods best suited to their own learning styles.

21.2.1 Drill and Practice

Drill and practice was the first widespread use of computer-based learning, developed almost as soon as computers became available. Teaching material is presented to the student, and the student is evaluated immediately via multiple-choice questions. The computer grades the selected answers and, based on the accuracy of the response, repeats the teaching material, or allows the student to progress to new material (Figure 21.1).

Although it can be tedious, drill and practice still has a role in teaching factual material. It allows the educational system to manage the wide variation in ability of students to assimilate material and frees up instructors for more one-on-one interaction where that technique is most effective. It also allows the instructor to concentrate on more advanced material while the computer deals with presenting the routine factual infor-

![Figure 21.1. Drill and practice. In this image-based quiz, the student is presented with a dissected part and is asked to identify the structure marked with a flag. The question is presented in a multiple-choice format. If he or she wishes, the student can switch to the more difficult option of typing in a textual answer. In typical use, students will use the multiple-choice option while learning the material and the free-text option when evaluating themselves. (Source: © 1994, Stanford University, and D. Kim et al. Screen shot from Kim et al., 1995.)](image-url)
mation. Studies at the elementary school level have found that it is the poorest students who benefit most from computer-based learning, primarily from drill-and-practice work that lets them catch up to their peers (Piemme, 1988).

21.2.2 Didactic: The Lecture

Although much of the focus of computer-based teaching is on the more innovative uses of computers to expand the teaching format, computers can be employed usefully to deliver didactic material, with the advantage of the removal of time and space limitations. A professor can choose to record a lecture and to store, on the computer, the digitized video of the lecture as well as the related slides or other teaching material. This approach has the advantage that relevant background or remedial material can also be made available through links at specific points in the lecture. The disadvantage, of course, is that the professor may not be available to answer questions when the student reviews the lecture (Figure 21.2).

Figure 21.2. Didactic teaching. A digital video lecture is presented within a browser for the Web. The video image in the upper left is augmented with high-resolution images of the lecture slides on the right. Because the whole is presented within a Web browser, additional information, such as links to other Web sites or to study material, could have been added to the Web page. (Source: ©2004, Stanford University. Screen shot of a digital video lecture.)
Another use of this method could be the immediate availability on the Internet of presentations from national conferences for interested health students and professionals unable to attend the meetings. With media reports of news from medical meetings often reaching patients the next day as newspaper headlines, physicians can now access the details of the reported news on the Web rather than waiting for published reports, which may lag many months behind the presentations.

An excellent example of how computer-based learning can go beyond the traditional lecture is the Howard Hughes Medical Institute Web site on teaching genetics. This multimedia textbook of genetics uses graphics, hot links, and photographs along with text to present a lively and entertaining series of lectures on genetic disease.

### 21.2.3 Discrimination Learning

Many clinical situations require the practitioner to differentiate between two apparently similar sets of clinical findings, where subtle differences lead to different diagnoses. Discrimination learning is the process that teaches the student to differentiate between the different clinical manifestations. A computer program, through a series of examples of increasing complexity, can train the student to detect the subtle differences. An example is a dermatologic lesion that comprises red rash and inflammation. A rash of the same appearance on different parts of the body can imply different diagnoses. The computer program begins with the differences between a few standard presentations of this lesion and, as the student learns to discriminate between these, presents additional types (Sanford et al., 1996).

### 21.2.4 Exploration Versus Structured Interaction

Teaching programs differ by the degree to which they impose structure on a teaching session. In general, drill-and-practice systems are highly structured. The system’s responses to students’ choices are specified in advance; students cannot control the course of an interaction directly. In contrast, other programs create an exploratory environment in which students can experiment without guidance or interference. For example, a neuroanatomy teaching program may provide a student with a fixed series of images and lessons on the brainstem, or it may allow a student to select a brain structure of interest, such as a tract, and to follow the structure up and down the brainstem, moving from image to image, observing how the location and size of the structure changes.

Each of these approaches has advantages and disadvantages. Drill-and-practice programs usually teach important facts and concepts but do not allow students to deviate from the prescribed course or to explore areas of special interest. Conversely, programs that provide an exploratory environment and that allow students to choose any actions in any order encourage experimentation and self-discovery. Without structure or guidance, however, students may waste time following unproductive paths and may fail to learn important material, the result being inefficient learning.

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1Howard Hughes Medical Institute Web site on teaching genetics. http://www.hhmi.org/GeneticTrail/

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21.2.5 Constrained Versus Unconstrained Response

The mechanism for communication between a student and a teaching program can take one of several basic forms. At one extreme, a student, working with a simulation of a patient encounter, may select from a constrained list of responses that are valid in the current situation. The use of a predefined set of responses has two disadvantages: It cues the student (suggests ideas that otherwise might not have occurred to him), and it detracts from the realism of the simulation. On the other hand, simulations that provide students with a list of actions that are allowable and reasonable in a particular situation are easier to write, because the authors do not need to anticipate all responses.

At the opposite extreme, students are free to query the program and to specify actions using unconstrained natural language. Computer recognition of such natural language, however, is just beginning to be feasible. An intermediate approach is to provide a single, comprehensive menu of possible actions, thus constraining choices in a program-specific, but not a situation-specific, manner. The use of a list of actions and a constrained vocabulary is less frustrating to those students who may have difficulty formulating valid interactions.

21.2.6 Construction

One of the most effective—but extremely difficult to implement on the computer—ways to teach is the constructive approach to learning. A relatively simple example is learning anatomy through reconstructing the human body either by putting together the separated body parts or by placing cross sections at the correct location in the body.

21.2.7 Simulation

Many advanced teaching programs use simulations to engage the learner (Gaba, 2004). Learning takes place most effectively when the learner is engaged and actively involved in decision making. The use of a simulated patient presented by the computer can approximate the real-world experience of patient care and concentrates the learner’s attention on the subject being presented.

Simulation programs may be either static or dynamic. Figure 21.3 illustrates an interaction between a student and a simulated patient. Under the static simulation model, each case presents a patient who has a predefined problem and set of characteristics. At any point in the interaction, the student can interrupt data collection to ask the computer consultant to display the differential diagnosis (given the information that has been collected so far) or to recommend a data collection strategy. The underlying case, however, remains static. Dynamic simulation programs, in contrast, simulate changes in patient state over time and in response to students’ therapeutic decisions. Thus, unlike those in static simulations, the clinical manifestations of a dynamic simulation can be programmed to evolve as the student works through them. These programs help students to understand the relationships between actions (or inactions) and patients’ clinical outcomes. To simulate a patient’s response to
intervention, the programs may explicitly model underlying physiological processes and may use mathematical models.

**Immersive simulated environments**, with a physical simulation of a patient in an authentic environment such as an operating room, have evolved into sophisticated learning environments. The patient is simulated by an artificial manikin with internal mechanisms that produce the effect of a breathing human with a pulse, respiration, and other vital signs. In high-end simulators, the manikin can be given blood transfusions or medication, and its physiology will alter based on these treatments. These human patient simulators are now used around the world both for skills training and for cognitive training such as crisis management or leadership in a team environment. The environment can represent an operating room, a neonatal intensive care unit, a trauma center, or a physician’s office. Teams of learners play roles such as surgeon, anesthetist, or nurse, and practice teamwork, crisis management, leadership, and other cognitive exercises. An extension of the physical human patient simulator is the virtual patient in a virtual operating room or emergency room. Learners are also present virtually, logging in from remote sites, to form a team to manage the virtual patient.

**Procedure trainers** or **part task trainers** have emerged as a new method of teaching, particularly in the teaching of surgical skills. This technology is still under development, and it is extremely demanding of computer and graphic performance. Early examples have focused on endoscopic surgery and laparoscopic surgery in which the surgeon manipulates tools and a camera inserted into the patient through a small incision. In the simulated environment, the surgeon manipulates the same tool controls, but these tools control simulated instruments that act on computer-graphic renderings of the operative field. Feedback systems inside the tools return pressure and other haptic sensations to the surgeon’s hands, further increasing the realism of the surgical experience. Simulated environments will become increasingly useful for all levels of surgery, beginning with training in the basic operations of incision and suturing and going all the way to complete surgical operations. Commercial trainers are now available for some basic surgical tasks and for training eye–hand coordination during laparoscopic procedures.

![Figure 21.3. A typical interaction screen in a sequential diagnosis problem with a simulated patient. The user interrogates the computer about history, physical findings, and laboratory test results of a simulated patient to reach a diagnosis. (Source: © 1993, Diagnostic Reasoning, Illinois. Screen shot from the Diagnostic Reasoning program.)](image-url)
21.2.8  **Feedback and Guidance**

Closely related to the structure of an interaction is the degree to which a teaching program provides feedback and guidance to students. Virtually all systems provide some form of feedback—for example, they may supply short explanations of why answers are correct or incorrect, present summaries of important aspects of cases, or provide references to related materials. Many systems provide an interactive help facility that allows students to ask for hints and advice.

21.2.9  **Intelligent Tutoring Systems**

More sophisticated systems allow students to take independent action but may intervene if the student strays down an unproductive path or acts in a way that suggests a misconception of fact or inference. Such mixed-initiative systems allow students freedom but provide a framework that constrains the interaction and thus helps students to learn more efficiently. Some researchers make a distinction between coaching systems and tutoring systems. The less proactive coaching systems monitor the session and intervene only when the student requests help or makes serious mistakes. Tutoring systems, on the other hand, guide a session aggressively by asking questions that test a student's understanding of the material and that expose errors and gaps in the student's knowledge. Mixed-initiative systems are difficult to create because they must have models both of the student and of the problem to be solved (Eliot et al., 1996).

21.3  **Current Applications**

Computer-based learning has been developed for the beginning medical student and the experienced practitioner: for the layperson and the medical expert. In this section, we present examples of actual programs that are being used to support medical education for each of these categories of learners.

21.3.1  **Preclinical Applications**

Traditional teaching in the preclinical years has been through lectures to large groups and laboratory exercises. With increasing laboratory costs and increasing amounts of information to be imparted to students, the individual, hands-on component of learning has decreased. Computer-based learning has the promise to return the student to individualized, interactive learning while reducing the need to teach in the lecture setting. Teaching programs have been developed for most subjects and using all styles of pedagogy. We describe here a few interesting programs for preclinical learning.

BrainStorm, developed at Stanford University, is an interactive atlas of neuroanatomy, with images of dissections and cross sections, diagrams, and extensive supporting text (Hsu, 1996). The unit of knowledge is a brain structure, such as nucleus, tract, vessel, or subsystem. Each unit has references to three modes of information presentation—image, diagram, and text—each of which contains representations of many
structures, the result being a richly connected network of information. When compared with hyperlinks on Web pages, which may lead the student astray from the original learning goal, a named link, such as a cross-reference to an image, contains information that helps the student to decide whether to follow that link and to retrieve the expected information. Multiple-choice quizzes on every image provide thousands of questions for self-evaluation. Animated simulations teach the basics of skills such as performing an examination for a cranial-nerve lesion.

The Digital Anatomist, at the University of Washington, Seattle, uses three-dimensional models of brain and anatomic structures to teach about anatomic structure and localization. A unique aspect of this program is its accessibility over the Internet. Using a client program, the student requests new views of the models. Rotations of the model are performed on the powerful server at the university, and the resulting images are sent to the student for viewing on the client program (Rosse et al., 1998).

The Visible Human male and female are an extraordinary resource available through the NLM.³ Thousands of cross sections represent the entire bodies of two humans. These data have been licensed freely by numerous sites that then use these images for teaching, for annotation of anatomic structures, for reconstruction of three-dimensional anatomy, for research on image processing and object segmentation, and for research on the development of large image databases.

 Developed by researchers at the Harvard Medical School, HeartLab is a simulation program designed to teach medical students to interpret the results of auscultation of (listening to) the heart, a skill that requires regular practice on a variety of patient cases (Bergeron and Greenes, 1989). Physicians can diagnose many cardiac disorders by listening to the sounds made by the movement of the heart valves and the movement of blood in the heart chambers and vessels. HeartLab provides an interactive environment for listening to heart sounds as an alternative to the common practice of listening to audiotapes. A student wearing headphones can compare and contrast similar-sounding abnormalities and can hear the changes in sounds brought on by changes in patient position (sitting versus lying down) and by physician maneuvers (such as changing the location of the stethoscope).

### 21.3.2 Clinical Teaching Applications

For many years, teaching hospitals usually had numerous patients with diagnostic problems such as unexplained weight loss or fever of unknown origin. This environment allowed for thoughtful “visit rounds,” at which the attending could tutor the students and house staff, who could then go to the library to research the subject. A patient might have been in the hospital for weeks, as testing was being pursued and the illness evolved. In the modern era of Medicare’s system of lump-sum payment for diagnosis-related groups (DRGs) and of managed care, such a system appears as distant as professors in morning coats. The typical patient in today’s teaching hospital is very sick, usually elderly, and commonly acutely ill. The emphasis is on short stays, with diagnos-

tic problems handled on an outpatient basis and diseases evolving at home or in chronic
care facilities. Thus, the medical student is faced with few “diagnostic problems” and
has little opportunity to see the evolution of a patient’s illness over time.

One response of medical educators has been to try to move teaching to the outpatient
setting; another has been to use computer-modeled patients. Simulated patients allow
rare diseases to be presented and allow the learner to follow the course of an illness over
any appropriate time period. Faculty can decide what clinical material must be seen and
can use the computer to ensure that this core curriculum is achieved. Moreover, with the
use of an indestructible patient, the learner can take full responsibility for decision mak-
ing, without concern over harming an actual patient by making mistakes. Finally, cases
developed at one institution can be shared easily with other organizations. Case libraries
are available on the Internet; examples include the AAMC Virtual Patients database and
geriatric cases from the University of Florida.

Clinical reasoning tools—such as DXplain, Iliad, and Quick Medical Reference
(QMR)—are discussed in Chapter 20. Although not typically thought of as educational
in the traditional sense, such diagnostic support systems can provide the ideal educa-
tional experience of giving aid to a physician or student when he or she is involved with
a real case and thus is most receptive to learning. Literature searching (Chapter 19) con-
fers the same advantages.

The National Board of Medical Examiners (NBME) has had a long-standing inter-
est in using computer-based case simulations for their examinations. These simulations
include cost as well as time considerations. The NBME has begun to use these cases in
their computer-based examination of medical students.

### 21.3.3 Continuing Medical Education

Medical education does not stop after the completion of medical school and formal res-
didency training. The science of medicine advances at such a rapid rate that much of
what is taught becomes outmoded, and it has become obligatory for physicians to be
lifelong learners both for their own satisfaction and, increasingly, as a formal govern-
ment requirement to maintain licensure.

Although the physician practicing at a major medical center usually has no problem
obtaining the required hours of accredited CME, physicians who practice in rural areas
or other more isolated locations may face considerable obstacles. Physician CME has
become a large industry and is widely available, but often the course fees are high, and
attendance also incurs the direct costs of lodging and transportation and the indirect
costs of time lost from practice. The cost of CBE is often much lower.

With increasing specialization and subspecialization has come an added difficulty.
Traditional lecture-based CME must aim at a broad audience. Therefore, many listen-
ers know as much or more about the topic than the speaker; many others find the mate-
rial too difficult or of little relevance. A pure subspecialist—even one at a major medical
center—may find the majority of CME offerings irrelevant to his or her practice. The

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5 University of Florida Web site on clinical teaching cases: [http://medinfo.ufl.edu/cme/geri/](http://medinfo.ufl.edu/cme/geri/)
ideal form of CME for many physicians would be a preceptorship with a mentor in the same discipline, but the costs of providing such an experience on a wide scale would be prohibitive. With the increasing amount of computer-based material available, including self-assessment examinations from specialty societies, specialists can select topics that are of interest to them. Well-known examples are the Medical Knowledge Self-Assessment Program (MKSAP) from the American College of Physicians, now in its 13th edition, which is available in print and on CD-ROM, and the American College of Cardiology’s Self-Assessment Program (ACCSAP), now in its 5th edition, and available in print, on CD-ROM, and online.

Both literature searching (Chapter 19) and use of diagnostic support systems (Chapter 20) are an important part of a physician’s continuing education. These aids to the diagnosis and management of complex patient problems reach the physicians when they are most receptive to learning new material. Clinicians must rely on and maintain a very large inventory of rapidly accessible information kept in long-term memory and less accessible resources kept on a bookshelf. To be effective, education need not be formally labeled as such. Often the best education for the practicing clinician occurs in the context of caring for a particular patient. When the “teachable moment” arrives, the education message may be delivered by a colleague or by a consultant, or it may be in the form of a chunk of knowledge delivered by an intelligent computer system. One of the more promising research activities involves the development of a just-in-time (Chueh and Barnett, 1997) approach to delivering knowledge-rich and problem-focused information during the course of routine clinical care.

21.3.4 Consumer Health Education

Today’s patients have become health care consumers; they often bring to the health care provider a mass of health-related information (and misinformation) gathered from the media. Medical topics are widely discussed in general interest magazines, in newspapers, on television, and over the Internet. Patients may use the Internet to join disease- or symptom-focused chat groups or to search for information about their own conditions. At the same time that patients have become more sophisticated in their requests for information, practitioners have become increasingly pressed for time under the demands of managed care. Shorter visits allow less time to educate patients. Computers can be used to print information about medications, illnesses, and symptoms so that patients leave the office with a personalized handout that they can read at home. Personal risk profiling can be performed with widely available software, often free from pharmaceutical firms. This type of software clearly illustrates for the patient how such factors as lack of exercise, smoking, or untreated hypertension or hyperlipidemia can reduce life expectation and how changing them can prolong it.

A torrent of consumer-oriented health sites have flowed onto the Web. As we discussed in Chapter 15, one problem that complicates the use of any information site on the Internet is lack of control. Consumers are not readily able to distinguish factual information from hype and snake oil. An important role for the health care provider today is to suggest high-quality Web sites that can be trusted to provide valid information. Many such sites are available from the various branches of the National Institutes
of Health (NIH) and from medical professional organizations. The American Medical Association maintains a Web site\(^6\) that includes validated information about such topics as migraine, asthma, human immunodeficiency virus (HIV), and acquired immune deficiency syndrome (AIDS), depression, high blood pressure, and breast cancer. The National Institute of Diabetes and Digestive and Kidney Diseases of the NIH has extensive consumer-oriented material\(^7\) that can be directly accessed by patients. Alternatively, physicians can use the site to print material for distribution to their patients. Most national disease-oriented organizations such as the American Heart Association and the American Diabetes Association now maintain Web sites that can be recommended with confidence. These sites provide additional links to numerous Web sites that have been evaluated for and found to meet a minimum level of quality. A good source of qualified material in a wide variety of topics is available for consumers in NLM’s Medline Plus.

### 21.3.5 Distance Learning

The Internet, and in particular the Web, has radically changed the way that we access information. It is now possible to earn university degrees from home at every level from bachelor’s to doctorate. Physician CME credit is increasingly available in the same way, in many instances free with pharmaceutical company sponsorship or at modest cost.

A widely used example is Medscape.\(^8\) Their Web site (http://www.medscape.com/cme-centerdirectory/default) offers hundreds of hours of AMA Category I CME for physicians at no cost. The user must register and endure pharmaceutical advertisements, but has no out-of-pocket costs. Medscape offers detailed reports of papers presented at many major medical meetings, appearing online within hours or days of the presentation.

Numerous Internet sites offer a teaching experience along with CME credit. Helix,\(^9\) sponsored by GlaxoWellcome but without obvious commercial bias, offers articles on nutrition, exercise, and fitness, each of which provides 1 or 1.5 hours of credit after the student completes a test. Grand Rounds on Frontiers in Biomedicine from the George Washington University School of Medicine is also available, in either text or video format. The Marshall University School of Medicine offers the Interactive Patient,\(^10\) a simulated case with which a physician can earn 1 hour of CME credit for a fee of $15. A good source of pointers to online medical education is maintained at the Online Continuing Medical Education site.\(^11\) This site provides a listing of Web educational resources organized by speciality or by topic, with almost 300 sites included.

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\(^10\)Marshall University School of Medicine’s “Interactive Patient” Web site: http://medicus.marshall.edu/.
\(^11\)Online Continuing Medical Education Web site: http://www.cmelist.com/list.htm
Many medical journals, such as the *New England Journal of Medicine* and the *Cleveland Clinic Journal of Medicine* offer online CME tests, with certificates printed immediately after the test is completed.

As we begin a new century, the Internet shows great promise for supporting distance education, but it still has many problems. The challenges facing a physician or a health care provider who is seeking education via the Internet are similar to those of any other user. Technical problems still abound, and the regular user of the Internet is subject to being disconnected in mid-use for no apparent reason. Those people who most need distance learning, such as rural practitioners, are least likely to have high-speed connections, and so are faced with very slow downloading of programs that make extensive use of graphics. In addition to technical problems, the anarchic nature of the Internet means that the environment still dictates caveat emptor. There is no way of telling in advance whether a listed CME program is of high quality, although restricting use to sites that offer AMA Category 1 credit provides some assurance of worthwhile content. Students must also be prepared to find that sites listed in reference guides no longer exist or have changed from the description in the reference guide.

### 21.4 Design, Development, and Technology

Creation of computer-based learning material requires a systematic process of design and implementation, using technologies appropriate to learning goals. We present some of the issues that arise in this process.

#### 21.4.1 Design of Computer-Based Learning Applications

In the past, each university or group developed its own approach to the design and implementation of its learning software. Developers at each site climbed a learning curve as they determined appropriate designs for pedagogy on the computer and the associated structuring of information. Although no broadly accepted method of design yet exists, a four-level approach to program design appears to be emerging independently at many sites. The four levels are structured content; query, retrieval, and indexing; authoring and presentation; and analysis and reasoning.

**Structured Content**

Early authoring tools, such as HyperCard and ToolBook, as well as tools for Hypertext Markup Language (HTML) contributed to a development approach in which the learning content, both text and media, was embedded inside the program, along with the code that presented the content and allowed navigation through the program. This intuitive approach to development had the beneficial result that engaging courseware was developed by numerous content experts who did not need to know complex programming languages. On the negative side, the content was difficult to maintain, expand, or modify because the content and its presentation were intermingled throughout the program. Understanding the functionality of a segment of code was also complicated.
because its operation might depend on many other segments scattered throughout the program. It is therefore desirable that content be maintained separate from the code for its presentation and navigation. Once content is externalized, it is necessary that the content be formatted in a predictable structure such that it can be read and correctly linked by a computer program.

**Structured content** is different from narrative text. A paragraph of text in a clinical report is narrative text. When the paragraph is broken into subsections, each subsection representing a coherent concept, with the name of the concept used as a tag or keyword to label that subsection, the paragraph has been converted to structured text. A database record, with fields, is a structured item. We can perform computations on a structured item other than simply displaying it. For example, a database can be searched for all occurrences of a specific type of content within a specified field. Another approach to structured content is seen in Extensible Markup Language (XML), a subset of Standardized General Markup Language (SGML) constituting a particular text markup language for interchange of structured data.

Structured content requires more than structuring for layout. It adds labels or tags for semantic structuring (Figure 21.4). The Digital Library Project (Fox and Marchionini, 1998) has developed sample document models and semantic tags for numerous domains, such as environmental engineering and computer science technical reports. Tags that indicate the title of an article, its author, and its date of publication are examples of semantic tags. In clinical material, tags can be developed at many different levels of specificity. A single tag may be used to indicate an entire section on physical examination of the patient. Alternatively, a tag could be used for each step of the examination. Careful design of semantic tags may allow content created for one learning purpose to be reused in other programs.

![Figure 21.4](Source: © 1998, Stanford University. A composite screen shot of the Short Rounds program and of the text file used in the program.)
Query, Retrieval, and Indexing

The second level of design of teaching programs is providing the ability for users to index into and retrieve desired content. Query and retrieval capabilities are rarely used in teaching programs, but indexing is often available. This difference is significant. An index is developed by the author either manually or automatically and is stored along with the program. The student can access only the terms and links made available by the author. Segments of the content that are not indexed cannot be accessed by the student through the index.

In query and retrieval, the terms are selected by the student. They can be matched against a predetermined index or, preferably, against a thesaurus that searches for synonyms, more global concepts, and more specific concepts. The system searches the content using the student’s terms and any other terms selected through the thesaurus. The entire searchable content can be accessed through this method. Queries that were not conceived of by the program’s author, such as one involving an unexpected combination of terms, can be executed by the student.

In unstructured content, searches are executed on the full text. If the content is structured, searches can be applied specifically to certain categories of information. This technique has the potential to increase the specificity of the search because the content is searched in the context (category) specified by the student.

Authoring and Presentation

The third level of teaching program design is programming for author support and for presentation. The ability of subject matter experts to develop courseware within a reasonable time frame depends on the availability of good authoring systems. The ability of the student to understand the program and to make good use of its content depends on the presentation of the content.

An authoring system allows the expert to focus on the content of the teaching program and to be unconcerned with the details of writing a computer program. Early teaching programs, using multimedia and hyperlinks, had their content and code intermixed. The content author was also the person programming the navigation and presentation of the content. He or she had to do both even if the programming was at a high level, such as creating flow diagrams for content navigation. An authoring system is based on the recognition that a content domain has a predictable structure—then the author is provided with a template that represents this structure. Content is entered into the template through familiar operations such as typing or importing a digital image. In microbiology, for example, a category of microbes is bacteria. For almost every type of bacteria, the following categories are required: description, pathogenesis, laboratory tests, clinical syndromes caused, and other bacteria that can also cause these syndromes. Similarly, every description of a patient’s case includes categories such as history, physical examination, tests and procedures, diagnosis, and treatment. A template based on domain structure not only provides a framework for authoring, but also allows multiple authors to create content in parallel, greatly speeding the authoring process.
The *presentation* includes the graphic design of the screen, the location and appearance of the content, the selection of the content to be presented, and the navigation to other content. Although there are numerous resources for guidance in graphic design and content presentation, little is known about how presentation affects the process of learning or the use of the content. Studying the use of the richly linked program for neuroanatomy, BrainStorm, described in Section 21.3.1, Hsu (1996) observed that students who were reviewing the subject made extensive use of annotated cross-section images and the related quizzes. On the other hand, students who were engaged in primary learning made significant use of the many textual resources in the program. The presentation was the same in both cases, but the users' objectives differed, leading to different uses of the program. A further question that has not been studied is whether manipulation of the presentation could have altered the usage. For example, if the program had detected significant study of brainstem nuclei and had prompted the student about the availability of diagrams that had not been examined, would a large number of students have chosen to examine these diagrams?

Teaching content available on the Web is characterized by a large number of links, many leading to material that is distracting for the serious learner. The value of these links lies in making available a large range of content. The student is often, however, unable to judge the quality and value of the content reachable by these links. Navigation support information that indicates the nature of the linked content could increase greatly the value of each such link.

*Content-driven* automated presentation systems are based on the use of structured content. The selection of content, the layout of the presentation, and the availability of linked information all can be driven by structured content. Figure 21.4 shows the contents of a text file containing structured content and the resulting multimedia presentation. On the one hand, the display program reads and parses the structured content, determining the text and links that will be displayed and the layout that will accommodate the necessary content. On the other hand, because the display is created anew each time, the author has the flexibility to use any terms desired to represent the findings to be displayed. For example, the author may choose to add a finding under the label “Diet,” remove the “Stool Characteristics” finding, and change the name of a finding from “Present Illness” to “Chief Complaint.” The presentation program will read this file of structured content and will delete the button “Stool Characteristics,” add a button for “Diet,” and change the name of the “Present Illness” button. The appropriate text will get linked to the new Diet button.

**Analysis and Reasoning**

The fourth level of design, analysis, and reasoning is frequently not included in a teaching program. A program with built-in automated assessment of students would have analysis capability. A program that observed the student's use of it and identified relevant missed material would be reasoning about the student's possible needs. Intelligent tutoring systems, discussed in Section 21.2.9, have this capability.
21.4.2 Application Development

The process for development of computer-based teaching material is similar to the process for almost any other software project (see Chapter 6). The process begins with identification of a need and a definition of what that need is. This step is followed by a system design and prototyping stage, accompanied by a formative evaluation process. Once the design of the software has been clarified, the software is implemented in the programming language of choice, and the teaching content is entered. The software is then integrated into the teaching process and is evaluated in use. Throughout, the design is guided by available standards for software design as well as for design of content structure.

Definition of the Need

Because the development process for teaching programs is labor-intensive and time-consuming, appropriate planning is essential. Defining the need for computer-based teaching in the curriculum is the first step. Are there difficult concepts that could be explained well through an interactive animated presentation? Is there a need for an image collection that exceeds that which is presented in the context of the lecture? Does the laboratory need support in the form of a guided tour through a library of digitized cross-section images? Could a quantitative concept be explained clearly through a simulation of the physiological or biochemical process, with the student being able to vary the important parameters? Is there a need for a chat group or a newsgroup to supplement the lectures or discussion sections? Would a central repository for course handouts reduce the load on departmental staff?

Assessment of the Resources

The availability and commitment of a content and teaching expert is an obvious necessity. The rich multimedia nature of most computer-based teaching programs implies that graphic, video, and audio media resources must be acquired or be available. Slides or video that are used in the classroom are supplemented by comments from the lecturer, which compensate for their deficiencies. These materials must stand on their own in a software program. Therefore, acquiring media of sufficient quality and comprehensiveness, along with the necessary release of rights, is an important next step in development. Supporting staff for the development process and the necessary funds are additional resources that must be considered.

Prototyping and Formative Evaluation

Significant scholarly work is needed in prototyping and evaluation, because so little is known about how technology can support medical teaching. Anecdotal results suggest that market research focus groups and small discussion groups with a facilitator can lead to significantly useful design changes in the early stages of development. Participatory development can clarify the focus of the project and modify it so as to make the tool more useful to students (Dev et al., 1998).
Formative evaluation (see Chapter 11) is conducted during the evolution of a project, sometimes at many stages: as the idea is being developed, after the first storyboards are prepared (storyboards are sketches of typical screens, with the interactive behavior indicated), during examination of comparable software, and as segments of the software are developed. During formative evaluation, developers must be prepared to make major changes in direction if such changes will increase the value of the project while retaining the overall goal and keeping the budget within the available resources.

Production

Prototyping determines the form of the teaching program, its goals, the levels of media inclusion and interactivity, the nature of the feedback, and other design parameters. Production is the process of executing this design for the entire range of content determined earlier. The requirements during production differ from those of prototyping. Adequate funding and staffing resources must be available at all times. Media must be acquired and processed to the specified standard, and content must be written. Because simultaneous authoring may be needed for different segments and multiple authors may need to review the same section, a method of content collection and version control must be set up. Regular integration of the content into the overall program is required so that any problems of scaling or compatibility will be determined early. Production should be embarked on only if it is very clear that the project is needed and that the resources for completion will be available.

Integration in the Curriculum

An important aspect of courseware development that is often overlooked is the integration of computer-based materials with the curriculum. Currently, most computer-based materials are treated as supplementary material; they are placed in libraries and are used by students or physicians on their own initiative. This use is valid, and the programs serve as valuable resources for the students who use them; however, an educator can use such materials more effectively by integrating them into the standard curriculum. For example, programs might be assigned as laboratory exercises or used as the basis of a class discussion.

One of the barriers to integration is the initial high cost of acquiring sufficient computing resources. The cost of the computer equipment has fallen drastically in recent years; even so, the cost of purchasing and supporting enough computers for a whole school to use would be a major item in the curriculum budget of a school. This consideration will become less important as more students purchase their own computers. A second, and important, barrier is the reluctance of faculty to modify their teaching to include references to computer-based material or to operate these programs in the context of their teaching. One of the most effective uses of these programs has been as a lead-in to a small group discussion, such as the presentation of a clinical case on the computer, with students choosing the questions to ask the computer.
Maintenance and Upgrades

Changes in content and changes in the computer operating system or hardware, as well as the discovery of problems with the program, necessitate regular maintenance and upgrades. At the same time, good design requires that any major change in teaching method should trigger iteration through the entire design cycle.

Standards

Maintaining a balance between evolution and standards is difficult but necessary. It is particularly difficult because the publicly acknowledged standards themselves change so rapidly. The standards that apply to teaching programs have to do with the metadata: the information that describes the content and thus adds structure to the content. The IMS Learning Resources Meta-data Specification\(^\text{12}\) and the Sharable Content Object Reference Model (SCORM)\(^\text{13}\) are metadata specifications that have gained widespread acceptance in the learning technology community.

An important value of standardization for sharing among groups is that content created by one group of developers or authors is available for use by another group of authors. Another result of standardization is that presentation and authoring programs can be developed in parallel with content creation. Furthermore, if the standard is upgraded, or if new features are added, programs can be created to convert automatically all material from the old standard to the new.

### 21.4.3 Technology Considerations

Technology considerations determine the cost and availability of the final teaching product. For example, a program can be delivered on a Web client, or the software designer can choose between developing for the Windows or the Macintosh operating system. True platform independence is a myth, but it is possible to restrict development to a subset of features such that the teaching program has a high probability of running on most computers. The choice of operating over the Internet versus processing on a local machine is a decision that is dependent on the source of the learning content and the performance requirements of the program. Teaching programs that draw on content at many locations on the Internet—such as image collections, digital video, and text reference material—will be restricted by the constraints of a Web client, including a restricted number of display and interaction features. On the other hand, Internet access is more desirable if the program accesses rapidly changing content or bibliographic sources such as Medline.

A need for high performance, or for very large volumes of content, will restrict usage to a local machine. In some cases, such as the use of three-dimensional models in the Virtual Reality Modeling Language (VRML), the model is obtained from a site on the Internet but is then manipulated and displayed locally. The availability of high-capacity storage devices, such as digital video disk (DVD), makes it possible to distribute large quantities of material, with the Internet used for updates, extension of content, and links to additional content.

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\(^{12}\)http://www.imsglobal.org/metadata.

\(^{13}\)http://www.adlnet.org
21.5 Evaluation

Evaluation of a new teaching or training method can measure numerous attributes of success: four levels of evaluation are commonly accepted. The first is the reaction of the student population to the new teaching method and how well the method is assimilated into the existing process of teaching. These measure the acceptability of the method. The second level of evaluation is the usability of the teaching program. The third level of evaluation measures whether the new teaching method actually had any impact on what the students learned. Here knowledge acquisition is measured. The fourth level measures whether the new method results in behavioral change because, in the final analysis, content and procedures learned by students should affect how they practice medicine.

21.5.1 Reaction and Assimilation

Many evaluation studies focus on the acceptability of a teaching program to teachers and students. This information is collected through questionnaires, subjective reports, and measurement of actual usage. Without this baseline information, interpretation of more sophisticated analysis may be difficult. These measures do not, however, inform the developer about the effectiveness of a teaching program.

21.5.2 Usability and Cognitive Evaluation

If we wish to measure whether the student understands the operation and capabilities of the program, numerous methods are available. Two complementary methods are the use of the videotaped encounter with the program and the use of the automatically generated log of the student’s interaction with the program.

The videotape encounter typically records the actions and words of the student as well as the events on the screen, often presented for analysis in a picture-in-picture format. The video transcript is then segmented into individual events or items. Subsequently, these items are categorized in terms of their cognitive aspects, such as “searching for button” or “selects link to additional information.” The researchers use the resultant list of cognitive transactions to identify major categories of usage, sources of success and frustration, and typical information-seeking patterns.

A computer-generated log file can be created if the teaching program is instrumented to record the student’s interaction with the program. It may be desirable to be able to select which types of interactions will be recorded. In an analysis of BrainStorm usage (Hsu, 1996), the granularity of recorded information ranged from detecting transfers between pages of information to detecting the selection of every click on a highly detailed annotated image. A computer-generated log file of student interactions can be processed automatically to detect frequency and patterns of usage. Figure 21.5 shows the pattern of transitions between four different types of information in BrainStorm. The students clearly preferred to study the cross-sectional images over all other types of information. A drawback of the automated log is the lack of any information about the student’s motives for the interactions. Researchers can gather such information by interrupting
selected interactions and requesting the student to type in a comment, but this method is intrusive and breaks the process of information acquisition.

### 21.5.3 Knowledge Acquisition

Evaluation of knowledge acquisition includes the question that is asked most often of developers: Is this computer program more effective than traditional methods of teaching the same material? This question has proved difficult to answer because of the many changes introduced when computer-based teaching is used. One of the most important confounding factors is the renewed attention that the professor pays to preparing teaching material because the course is to be taught in a new format. Perhaps the most interesting evaluation questions are: In what ways is computer-based learning different from traditional methods of learning? Can computers enable learning in ways never before possible? Going further, can computers perform evaluations of knowledge acquisition that would be impossible using traditional written or oral examination techniques?

An example of computer-based evaluation is the evaluation of nonverbal knowledge of spatial location in anatomy (Friedman et al., 1993). The rationale was that the better a person knows anatomy, the more accurately he or she will recognize and localize an image of a cross section of the human body. The authors developed a computer game in which the examinee was given an outline of a cross section, with no internal structures displayed, and was asked to position it on a drawing of the human body. The examinee could request additional clues, the clues being pictures of organs in the cross section. After each clue, the examinee was asked to make an attempt to position the slice in the body. Requesting too
many clues resulted in a penalty that reduced the maximum possible score. The final score was based on the accuracy of the placement and the number of clues requested. The test differentiated between first-year medical students, fourth-year medical students, and anatomy faculty in their mastery of anatomic knowledge.

21.5.4 Problem Solving and Behavioral Change

The ultimate goal of medical knowledge acquisition is to improve a student’s ability to solve problems through application of that knowledge. In some cases, particularly in skill acquisition, such as insertion of an intravenous line, or in interpersonal interaction, such as history taking, the measure is not problem-solving ability but rather behavioral change.

21.6 Conclusion

CBE systems have the potential to help students to master subject matter and to develop problem-solving skills. Properly integrated into the medical school curriculum and into the information systems that serve health care institutions and the greater medical community, computer-based teaching can become part of a comprehensive system for lifelong education. The challenge to researchers in computer-based teaching is to develop this potential. The barriers to success are both technical and practical. To overcome them, we require both dedication of support and resources within institutions and a commitment to cooperation among institutions.

Suggested Readings

This article, by the pioneer in human patient simulators, presents many of the uses of this simulation technology.
This book presents a multilevel system for evaluating training programs.
The authors describe their clinical teaching program and present a thoughtful evaluation of its efficacy in learning.
The authors present a controlled randomized study of the efficacy of a new simulator.
Rosse’s group has developed one of the more comprehensive representations of a domain, in their case, anatomy. Such domain knowledge representation will be necessary for the next generation of educational software systems.


**Questions for Discussion**

1. What are two advantages and two limitations of including visual material in the following teaching programs:
   a. A simulated case of a patient who is admitted to the emergency unit with a gunshot wound
   b. A lecture-style program on the anatomy of the pelvis
   c. A reference resource on bacteria and fungi

2. You have decided to write a computer-based simulation to teach students about the management of chest pain.
   a. Discuss the relative advantages and disadvantages of the following styles of presentation: (1) a sequence of multiple-choice questions, (2) a simulation in which the patient’s condition changes over time and in response to therapy, and (3) a program that allows the student to enter free-text requests for information and that provides responses.
   b. Discuss at least four problems that you would expect to arise during the process of developing and testing the program.
   c. For each approach, discuss how you might develop a model that you could use to evaluate the student’s performance in clinical problem solving.

3. Examine two clinical simulation programs. How do they differ in their presentation of history taking or physical examination of the patient?

4. Select a topic in physiology with which you are familiar, such as arterial blood–gas exchange or filtration in the kidney, and construct a representation of the domain in terms of the concepts and subconcepts that should be taught for that topic. Using this representation, design a teaching program using one of the following methods: (1) a didactic approach, (2) a simulation approach, or (3) an exploration approach.

5. Describe at least three challenges you can foresee in dissemination of computer-based medical education programs from one institution to another.

6. Discuss the relative merits and problems of placing the computer in control of the teaching environment, with the student essentially responding to computer inquiries, versus having the student in control, with a much larger range of alternative courses of action.