# 23 Computers in Health Care Education

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

- How can computers improve the delivery of in-class and self-learning, as well as in-practice learning?
- How can constructivist approaches to learning be implemented using computers?
- How can 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?

## 23.1 Introduction

The current view of a desirable approach to health care education is one that acknowledges that medicine is practiced in a multi-disciplinary team environment in an information-rich world where constant learning is required to deliver high quality medical care. However, the actual practice of health care education remains primarily a **Flexnerian** one of science-based acquisition of medically relevant knowledge, followed by on-the-job apprentice-style acquisition of experience, and accompanied by evolution and expansion of the curriculum to add new fields of knowledge (Flexner 1910). The power of information technology today promises to transform the traditional Flexnerian learning model to a new one that applies information technology for successfully using the increasing volume of knowledge, learning evidence-based medical practice, collecting and critically analyzing data, collaborating through connectivity, distance learning and simulation-based learning, as well as team training.

This needed evolution of health care education is discussed by Frenk et al. (Frenk 2010) and is summarized in Table 23.1. Learning the scientific basis of medicine was an immensely important step that was driven by acceptance of the Flexner approach in the early twentieth century. An unfortunate corollary was the increasing use of lectures and, over the decades, reduced students' access to actual work with patients. It also led to ever-increasing specialization and loss of perspective of the health condition of the whole patient. In the 1960s, McMaster University in Canada pioneered a new approach, **problem-based learning**, where

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**Table 23.1** Evolution of health care education systems

| Basis of health care education | Science based | Problem based | Systems based |
|---|---|---|---|
| Instruction (can precede or be simultaneous with Training experience) | Scientific curriculum | Problem-based learning | Competency-based learning |
| Training experience | In-hospital basic training, then discipline-specific training | In-hospital and community-based basic training, then discipline-specific training | In-hospital and community-based basic training, multidisciplinary team experience, and discipline-specific training |

Adapted from Frenk et al. 2010

small groups of students, supported by a facilitator, learned through discussion of individual case scenarios (Neville 2009). This problem-based approach was proposed as an alternative to didactic lectures, supporting individualized learning, and placing this learning in the context of the patient rather than the context of a single discipline. More recently, a renewed examination of the health care process, the sources of medical error and the need for higher quality of care, have highlighted the systems aspect of medical care (Kohn et al. 2000). From the systems perspective, learners need to be taught the linkages and complexity of the many hospital systems, as well as bodies of knowledge that are brought to bear on the treatment of a single patient, and how to use information technology to support them in the care of the patient.

## 23.2 Theories of Learning

Understanding how computers can support this evolution of education in the health sciences requires understanding how individuals learn, and how we can support this process through teaching. Educational software and other applications are tools for education, not education itself. In order to use a tool appropriately, one must understand how the tool and its design relate to the task, as well as the task's context, goals and outcomes. We therefore present a brief review of what we know about how people learn (see also Chap. 4).

**Behaviorism**, originating in the field of psychology in the early 1900s, stipulated that understanding the working of the mind could be reduced to the study of observable behaviors and the stimulus conditions that caused them. Behaviorists argued that learning mainly consists of making connections between stimuli and responses. However, not all mental processes, such as understanding, reasoning and thinking, can be observed or made observable. Behaviorism was thus not only limited in the degree to which it could explain the process of learning, but also in how it could help educators determine how to influence it.

**Cognitive science** (see Chap. 4), arising in the 1970s, began to model the mind as an information processing system. In the cognitive view, the mind perceives information from external stimuli, represents it internally, and transforms it through mental processes. The cognitive approach to learning posits that even though learning can be inferred from behavior, it is separate from the behavior itself. Rather, learning is a permanent change in cognition that is the result of experience. Cognitive science allowed educators to view the brain not as a black box, but as a dynamic, changeable system.

Today's view of learning is dominated by the constructivist view, epitomized by the problem-based learning approach described above. **Constructivism** argues that humans generate knowledge and meaning from an interaction between their experiences and their ideas. It does not consider the student's head to be an empty vessel to be filled with information and knowledge, but suggests that teachers must actively consider what students already know and think about a subject when educating them. Problem-based learning, in which students receive a problem and research potential answers/solutions in a group, is based on this constructivist approach to education. Instead of emphasizing the learning of a large and complete body of knowledge, problem-based learning is focused on the process of arriving at a solution through accessing and using a body of knowledge. Today, it is commonly used in health professional education.

Bransford et al. (2000) emphasize three key findings from educational research that are also highly important for health science education:

- *Students have preconceived notions about what they learn, regardless of whether they are aware of them or not. Teaching must take make these notions explicit and work actively to change them when necessary.* Numerous experiments show that pre-existing conceptions persist among older students even in the face of evidence refuting the validity of existing mental models. The process of education, therefore, must pay attention to a learner's pre-existing knowledge and beliefs, use this knowledge as a starting point for instruction, and monitor how students' conceptions change as instruction proceeds.
- *To become competent, students must have a deep foundation of factual knowledge that is embedded in an appropriate conceptual framework. They must be able to organize knowledge in ways that facilitate retrieval and application.* Research on medical cognition has shown that expert performance, for instance in diagnosis, requires a richly structured information base. Therefore, students should not only learn facts, but also be able to use and connect these facts in the right way. This "learning with understanding" implies that students transform facts into usable knowledge.
- *Students should not only be able to learn, but also assess what and how they learn. This "metacognitive" approach helps them define their own learning goals and monitor their progress in achieving them.* Health science education attempts to produce the "lifelong learner," i.e. the professional who can recognize and remedy knowledge deficits over time. Reflecting this goal, many states in the US require physicians, dentists and nurses to complete a defined number of continuing education hours annually.

How can computers be used to help teachers implement these approaches to learning? We discuss computers as tools for teaching next.

## 23.3 Computers as Tools for Teaching

Various pedagogic designs can be implemented using computers, supporting any of the learning theories above. It is valuable, therefore, to understand how these pedagogic designs are implemented when one is determining how to use computers to support the objectives of the educational program. As examples, we discuss how to support seven different types of learning methods using computers: (1) drill and practice, (2) didactic learning in lectures, (3) exploration versus structured interaction, (4) scenario-, case- and problem-based learning, (5) learning through design, (6) simulation and, lastly, (7) intelligent tutoring systems, mentoring, feedback and guidance.

### 23.3.1 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, who 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 (Fig. 23.1).

Although it can be tedious, drill and practice still has a role in helping students learn 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

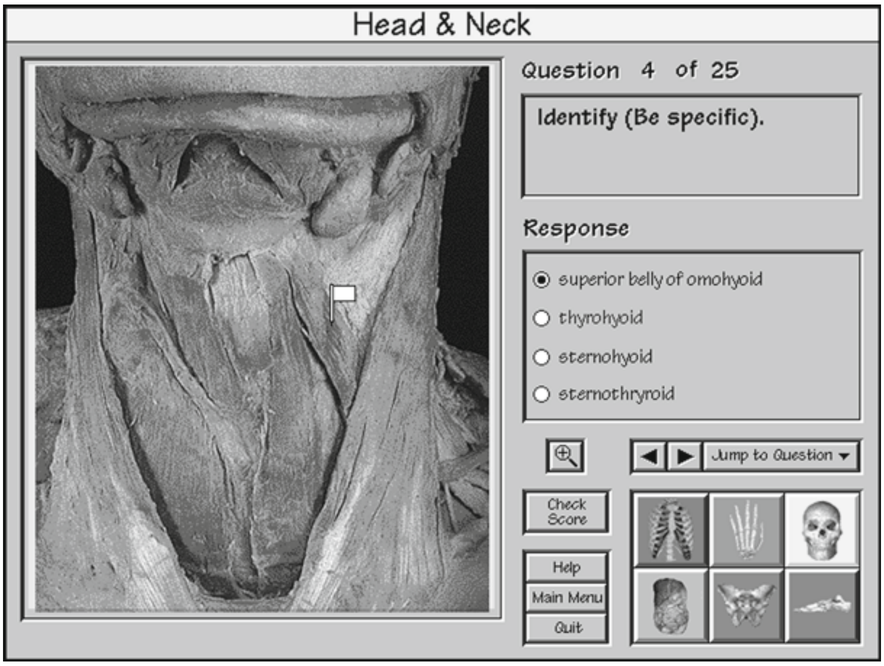


**Fig. 23.1** Drill and practice. In this image-based quiz, the student is presented with a dissected part and is asked to identify the structure marked with a flag. The question is presented in a multiple-choice format. If he or she wishes, the student can switch to the more difficult option of typing 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: Parvati Dev with permission)

while the computer deals with presenting the routine factual information. This tool is easily adapted to game-based formats, allowing competition, collaboration and team play to add interest to the learning of routine material.

### 23.3.2 Digital Lectures

Although much of the focus of computer-based teaching is on the more innovative uses of computers to expand the range of available teaching formats, 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 (Fig. 23.2).

This approach is widely used for webinars and podcasts – essentially lectures that are available online with or without accompanying slides and video. Such content is available at iTunes University, through the iTunes application, as well as on popular Web video sites, such as YouTube, and slide sharing sites, such as SlideShare. The Open Course Ware movement, originating at the Massachusetts Institute of Technology in 2001, makes lectures and accompanying material freely available on the Web sites of member universities.[1]

### 23.3.3 Exploration Versus Structured Interaction

Teaching programs differ in 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

[1] http://www.ocwconsortium.org/. (Accessed 9/15/2013). A large collection of public health lecture slides are also available at http://www.pitt.edu/~super1/ (Accessed 9/15/2013).

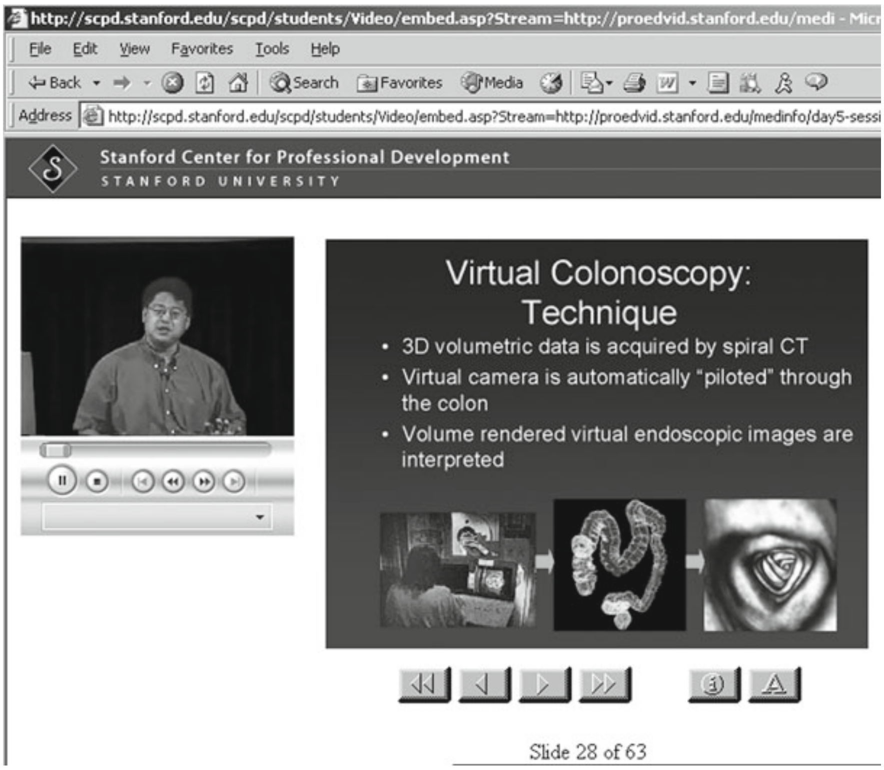


**Fig. 23.2** Didactic teaching. A digital video lecture is presented within a browser for the Web. The video image in the upper left is augmented with high-resolution images of the lecture slides on the right. Because the whole is presented within a Web browser, additional information, such as links to other Web sites or to study material, could have been added to the Web page (Source: Parvati Dev, with permission)

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. Fixed path learning programs ensure that no important fact or concept is missed but they 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.

An example is the Tooth Atlas, used in dentistry (Fig. 23.3). Understanding tooth three-dimensional structure is important for clinical dentistry. The key instructional objective of the program is to help students learn the complex external and internal anatomy of the variety of teeth in three dimensions. The rich, interactive, 3D visualizations show teeth as they would be visually perceived as well as through very high resolution computed tomography scans, radiographs and physical cross-sections. The learners rotate and section the computed models, and can control the transparency of each structure so as to study inter-relationships. While the visualization is highly exploratory, the embedded pedagogy is very structured, consisting of detailed textual quizzes with multiple-choice answers.

### 23.3.4 Scenario-, Case- and Problem-Based Learning

In this type of instruction, the computer presents the learner with a story that includes a problem. The presentation may be only in text, with text and graphics, or as an interactive movie in a near-realistic three-dimensional environment that replicates a space such as a clinic. The learner's role may be constrained such that the learner knows who they represent, what resources are available, and what the problem is that must be solved. Alternatively, the learner may be required to investigate the situation (examine the patient), define the problem, find any supporting resources

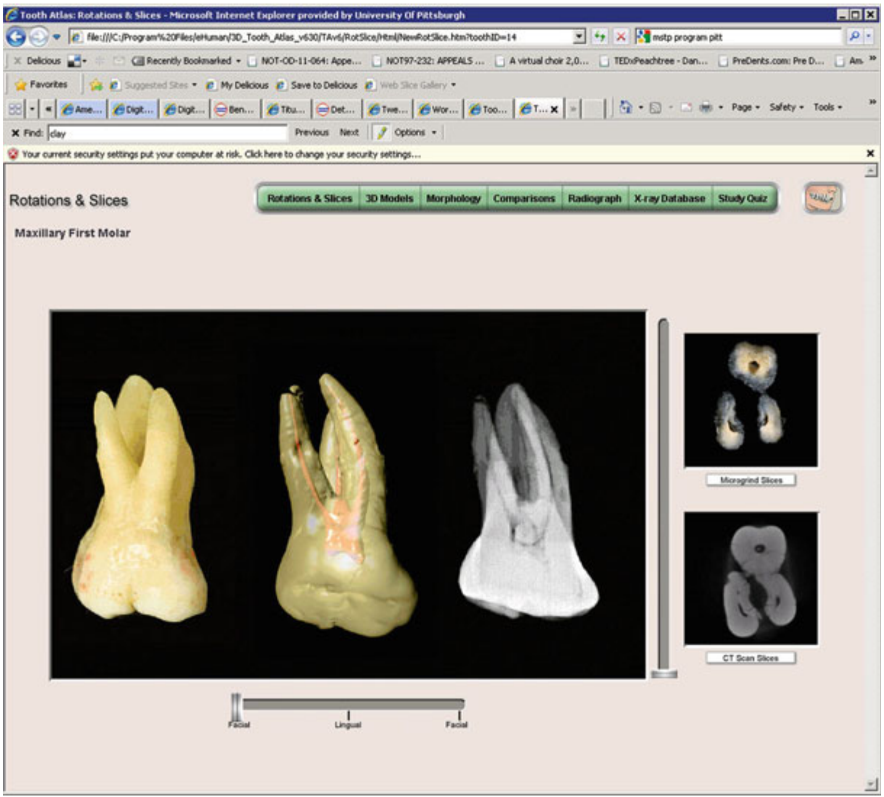


**Fig. 23.3** The Tooth Atlas offers free exploration in the domain of dental anatomy. Each tooth is represented (from *left*) in a photograph, 3D model and radiograph that the student can rotate freely. In addition, cuts following the transversal plane are available on the *right* (Reproduced with permission of Eric Herbranson)

(what imaging and laboratory tests are available or what learning resources are at hand) and guide the scenario to an end goal. As the learner proceeds, the scenario evolves on the computer based on the actions taken and the progress of time.

Tales from the Heart, produced by McMaster University, is a case-based program for learning the basic concepts of cardiology. It illustrates principles of heart disease by presenting patient cases with different cardiologic conditions and explaining the physiological basis for the observed clinical phenomena. The major goal of the program is to enable the learner to link clinical reasoning to principles of applied physiology. Each module begins with a brief story of the clinical presentation. It then discusses the physiological basis for the clinical presentation (Fig. 23.4), and presents the student with periodic decision points to assess understanding. The student's responses, whether correct or not, are positively reinforced with feedback designed to illustrate how applied physiology facilitates the diagnosis and rationalizes an approach to management.

An approach that combines the benefits of exploration with the constraint of a linear path through the material is one that breaks the evolving scenario into a series of short vignettes. A situation is presented, information and action options are available, and a decision must be made. Each decision triggers the presentation of the next vignette. This could lead to a branching story line but, usually, the next vignette presents the result of the best actions from the previous vignette. A scenario about a virtual patient could have vignettes that lead the learner through the steps of diagnosis, tests, and the course of treatment. This approach is commonly used in computer-based testing of clinical knowledge where assessment of learner performance would be extremely difficult if the interactions were completely unconstrained.

The ability of the computer to track and store the learner's actions allows post-processing and analysis of the tracked data. An interesting analytic capability is one that compares the performance of novice learners and experts to detect features that define expert information gathering or action sequences. Stevens et al. (1996) compared the information gathering and the conclusions of novices and experts on a set of

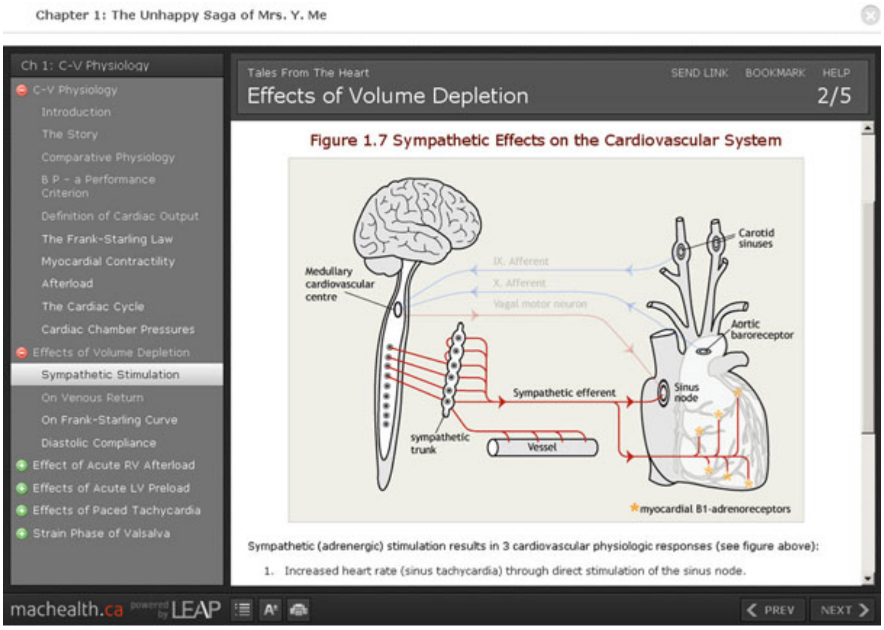


**Fig. 23.4** In Tales from the Heart, students study the neurological and physiological basis of cardiology in the context of a patient case (Reproduced with permission of Anthony J. Levinson)

immunological cases. They analyzed the performance data using **artificial neural networks** and were able to detect consistent differences in the problem solving approach of novices compared to experts. In particular, novices exhibited considerably more searching and lack of recognition of relevant information while experts converged rapidly on a common set of information items. The potential of demonstrating such expert patterns of performance to learners as a new learning tool has not been widely explored in the health sciences.

### 23.3.5 Learning Through Design

In learning through designing, students are required to construct something. The process of construction in itself is expected to teach the student new content. A simple example is when a student is asked to become the teacher. The act of preparing the material to be taught, and then teaching it to learners who each have a different grasp of the material, often results in excellent learning by the student teacher. Moving this concept to the computer, teachers have asked students to create Web sites, games, virtual patient simulations, and other constructs, as learning tools for other students. Learning through design can be a powerful learning tool but is not used much in the health sciences because it is perceived to be too time-consuming for the benefit received. Lack of teacher understanding of this tool is another reason that the method is rarely used.

### 23.3.6 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 23.5 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

**Fig. 23.5** The learner can select tools from the medical kit on the right, and drag them onto the simulated patient to clean and compress the wound or to listen to heart and lung sounds

**Fig. 23.6** This plastic mannequin simulates many of the functions of a living patient, including eye opening and closing, breathing, heart rate and other vital signs. Gases, medications, and fluids can be administered to this mannequin, with resulting changes to its simulated vital signs

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 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 (Fig. 23.6). In high-end simulators, the manikin can be given blood transfusions or medication, and its physiological response will change 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 (Fig. 23.7). 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. Products such as Second Life[2] and CliniSpace[3] are being used to construct and deliver these virtual medical environments.

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

[2] http://secondlife.com/ (Accessed 9/15/2013)

[3] http://www.clinispace.com/ (Accessed 9/15/2013)

**Fig. 23.7** Three-dimensional computer-generated virtual medical environments are used to present clinical scenarios to a team of learners. Each learner controls a character in the scenario and, through it, interacts with devices, the patient, and the other characters. Learning goals may include medical goals such as stabilization of the patient, communication goals such as learning to point out an error to more senior personnel, or team goals of leadership and delegation

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.

### 23.3.7 Intelligent Tutoring Systems, Mentoring, 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.

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).

Beginning health sciences students are building their fundamental knowledge. This knowledge is stored and is applied only to simple biomedical problems where they can identify basic symptoms and generate immediate diagnoses. As they progress to clinical problems, they acquire procedural knowledge, where they link basic knowledge to real situations. Ideally, they learn to develop hypotheses and establish or reject strategies, that is, they learn clinical reasoning. However, some students tend to learn the case as an entity without progressing to a problem solving approach. Experienced physicians continue to accumulate experience and learn to generalize from a set of cases to a set of rules that they can apply to circumstances that they have never encountered before. In health science education it is difficult to detect the cognitive level of the learner and thus apply an appropriate pedagogical strategy. The potential of intelligent tutoring systems to interrogate the learner and identify reasoning gaps is tantalizing but is yet to be realized.

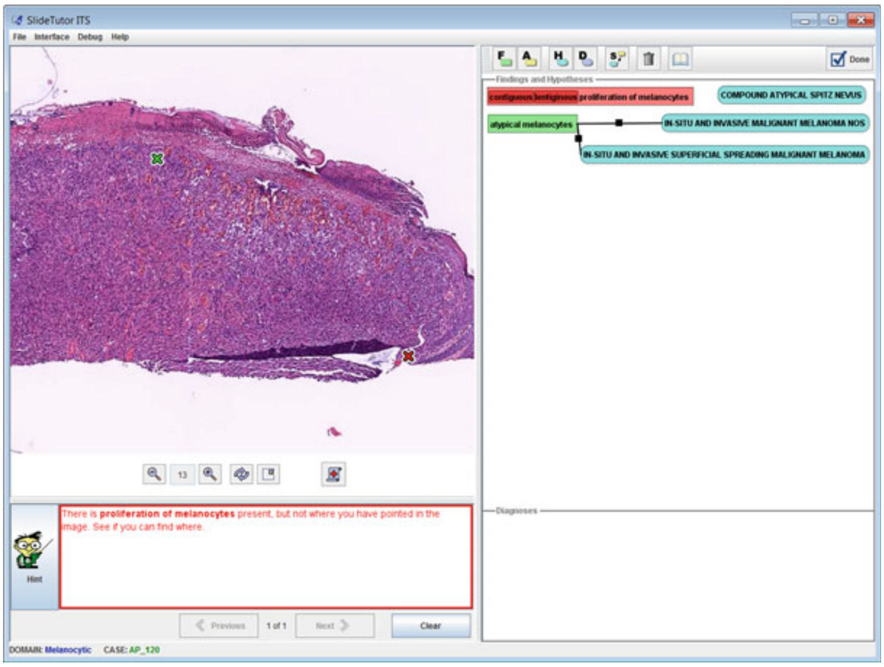


**Fig. 23.8** In this illustration from SlideTutor, the student has correctly identified the proliferation of melanocytes. However, SlideTutor provides the hint that the location of this finding is incorrect (Reproduced with permission of Rebecca Crowley)

SlideTutor is an example of an intelligent tutoring assistant, supporting a "virtual apprenticeship" in pathology. It simulates a student sitting at a double-headed microscope across from an expert pathologist and working through clinical cases. As the student explores the histologic slide, the system records what parts of the digital slide the student has examined, which findings and diagnoses were reported, and continuously analyzes these data to see whether the student is on the right track. If necessary, it corrects the student's approach and provides hints (Fig. 23.8). It has other intelligent functions that model student progress and help students write correct reports with the help of natural language processing. Evaluation studies have shown that the intelligent tutoring system is highly effective. On average, students improve their diagnostic and reporting performance by a factor of four after as little as 4 h of use of the system (Crowley et al. 2007).

## 23.4 Uses of Technology to Support Learning

The ubiquity of technology-supported learning is apparent when one considers the many different ways in which it is used.

### 23.4.1 Medical, Nursing, Dental and Other Health Science Students

Basic science programs in medical schools were among the first in their implementation of technology-supported learning. Visually rich content in anatomy, neuroanatomy and pathology was much more accessible on the computer than through the microscope or via the cadaver dissection room. Excellent 3D learning programs for anatomy are available, including Netter Interactive 3D, Primal Pictures, eHuman, Visible Body, Osirix, and other companies, providing ever more accurate visualization of the 3D human. The use of microscopes among basic science students has virtually disappeared. Interestingly, in many schools, the use of cadavers has seen a resurgence, both as an important learning tool and as a rite of passage into the health care profession.

Nursing schools entered the use of technology later but have moved quickly to expand its use in education. One area in which they have a strong lead is the use of physical manikins for simulation of realistic nursing scenarios. Nursing schools that used to share a simulation center with a medical school have found their own demand high enough to require building their own simulation centers.

Dental schools often share parts of their curriculum with medical schools, and as a result use the same or similar learning content. However, they also need specialized anatomical and simulation content for dental and craniofacial topics. 3D software for dental anatomy is used widely in predoctoral dentistry. Historically, simulation of dental procedures was practiced using physical objects such as chalk or plastic teeth, a practice that is still widespread. More recently, high fidelity digital simulators have been developed.

For many years, teaching hospitals had patients with interesting diagnostic problems such as unexplained weight loss or fever of unknown origin. This environment allowed for thoughtful "visit rounds," at which the attending physician 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 white lab 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 diagnostic problems handled on an outpatient basis and diseases evolving at home or in chronic care facilities. Thus, the medical student is faced with fewer diagnostic challenges 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 making, without concern over harming an actual patient by making mistakes. Finally, cases developed at one institution can be shared easily with other organizations. A well-known case library is MedEd PORTAL's Virtual Patients database from the Association of Medical Colleges (AAMC).[4]

### 23.4.2 The Practicing Professional, Continuing Education and Certification

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

The practicing health care professional must maintain their certification through a prescribed number of hours of professional education. In addition, there is a need to have each person certified every few years in key clinical processes such as Advanced Trauma Life Support and Advanced Cardiac Life Support. While many do learn these in classroom courses, the availability of online courses that can be taken at one's convenience, have made these digital courses popular. An additional advantage of an online certification course is the automatic tracking of learner performance, and the accompanying automatic generation of institutional compliance reports.

### 23.4.3 Health Informatics Education

Health information technology (HIT) systems are considered key components in creating safer hospitals and in improving quality of care. Implementation of these HIT systems has required hospitals and clinics to purchase the requisite hardware and software. However, it has become clear that effective implementation and use of these systems will require that the

[4] https://www.mededportal.org/ (Accessed 9/15/2013)

average health care professional also be trained in the principles of health care informatics. Information management is a major activity of health care professionals and its effective use can lead to better decision making for patients as well as better management of the clinical practice.

The **American Medical Informatics Association** (AMIA) offers a program, "10×10 courses", for graduate-level training of health care professionals in the application of informatics.[5] The federal government sees a need for over 10,000 health IT professionals, and has invested in setting up informatics workforce development through training in community colleges and degree programs.[6]

### 23.4.4 Curriculum Inventory

Learning objectives or competency objectives are operationalized through the definition of a curriculum. These curricula differ between institutions based on the available teaching resources and specific local interests and needs. The AAMC has maintained an inventory of the curriculum at each medical school through its CURRMIT (curriculum information management tool) database, which has now evolved into the Curriculum Inventory Portal. The existence of this database supports some useful functions such as allowing a school to benchmark its curriculum against other schools with similar demographics, or allowing researchers to study curricular profiles across schools.

The Curriculum Inventory Portal uses the **Medbiquitous** standards (see Sect. 23.5.5, below) for competencies and learning objectives. It currently holds the curricula for basic medical education. The goal is to expand to incorporate graduate medical education and practicing professionals. At the graduate level, specification of curricula is determined by the specialty societies, and implementation across schools is variable. Access to pooled information will be an impetus to improve the quality of the curriculum at each school.

### 23.4.5 Consumer Health Education

Today's patients are now repositioned as 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 on the Internet. Eighty percent of Internet users look for health care information (Pew 2011) online. Patients may use the Internet to join disease- or symptom-focused chat groups or to search for information about their own conditions. One in four Internet users with a chronic condition say that they have gone online to find others who share their health concerns (Pew 2011).

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 for 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 provided for free by 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 has flooded the Web. As discussed in Chap. 15, one problem that complicates the use of any information site on the Internet is lack of control. Many 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

[5] http://www.amia.org/education/10x10-courses (Accessed 9/15/2013)

[6] http://healthit.hhs.gov/portal/server.pt/community/healthit_hhs_gov__workforce_development_program/3659 (Accessed 1/8/2013)

from medical professional organizations. Good sources of qualified material in a wide variety of topics are available for consumers in National Library of Medicine's **Medline Plus**, the Centers for Disease Control and Prevention, and commercial sites such as **WebMD**. These sites provide additional links to numerous Web sites that have been evaluated for and found to meet a minimum level of quality. Most national disease-oriented organizations such as the American Heart Association and the American Diabetes Association also maintain Web sites that can be recommended with confidence.

## 23.5 The Ecosystem of Computers in Health Sciences Education

### 23.5.1 Accessing Learning Content: The Web

Eighty percent of Internet users look online for health information (Pew 2011). While this includes users of the Internet who are not health care professionals, it indicates the richness of available medical information. For the health science learner, there are numerous well-structured sources of learning content on the Internet. The federal agencies maintain portals such as the NLM's immense online library and bibliographic search facility as well as the other informational pages maintained by the various institutes and centers within the National Institutes of Health, the Agency for Health Care Research and Quality's content for team training and patient safety training, and the Centers for Disease Control and Prevention's health topics. The AAMC maintains the MedEd Portal, a peer-reviewed collection of medical and dental learning materials, including a rich collection of virtual patient cases (see Sect. 23.4.1). Medscape's professional site, emedicine, makes available detailed, professionally authored summaries of all major diseases and their management.[7] Collections such as Up-To-Date[8] and Ovid[9] provide integrated access to a selection of journals and books to which the institution chooses to subscribe.

At many academic health centers, the medical library takes on the role of curating and making available Web portals for each subspecialty. For example, a portal for obstetrics and gynecology may include access to the key research and clinical journals in the field, digital versions of the key specialist textbooks, databases from national and global sources, evidence and consensus summaries, image collections and teaching videos, drug references and calculators, and information for patients.

The electronic medical record (EMR) has the potential to be a point-of-service learning tool for much of this information. The advantage of embedding access to this information in EMRs is that it supports "**just-in-time learning**" within the context of patient care. Educational research has shown that learning under these circumstances can be particularly effective. Decision support and alert tools built into the EMR can include information that teaches the clinical reasoning behind the alert or the suggested decision. Some EMR products support interfaces to third party knowledge products such that queries within the EMR can link to external knowledge bases. An example, **Infobuttons** (see Chap. 12), provide context-specific links from one information system, such as the EMR, to some other resource that provides relevant information.[10]

### 23.5.2 Accessing Learning Content: Learning Centers

Learning centers originally provided a location where students could access computers on campus. Now learning centers are distributed organizations that support all academic technology needs that are not part of the function of the library. Typically these include centralized computer centers as before, numerous locations with one or two computers for brief uses, management of the

[7] http://emedicine.medscape.com/ (Accessed 9/15/2013)
[8] http://www.uptodate.com/ (Accessed 9/15/2013)
[9] http://www.ovid.com/ (Accessed 9/15/2013)
[10] http://www.infobuttons.org/ (Accessed 9/15/2013)

technology within the classrooms to support smart boards, video recording, polling and other functions, authoring of content by local faculty and students, management of computerized test taking, and integration of all teaching functions with the local learning management system.

Learning centers also have the task of acquiring appropriate digital learning content for the institution. These may be recommended by faculty but often have to be reviewed and selected from the vast collection of content available commercially or for free. If the content is to be created by a local faculty member, the learning center provides the expertise for this development.

As in any other profession, the manager of the learning center is expected to be familiar with the state-of-the-art in support and delivery of computer-supported learning. The AAMC's Group on Educational Affairs maintains a subgroup that organizes conferences and workshops for the leaders of learning centers and others interested in learning technologies.

### 23.5.3 Accessing Learning Content: Simulation Centers

A **simulation center** is a specialized type of learning center, though its governance may reside in an academic department such as anesthesiology or surgery depending on the center's origin and history. Immersive, simulation-based learning is a bridge between classroom learning and real clinical experience. Simulation technologies are used to create realistic clinical experiences in which learners can practice in safety. They have the freedom to make mistakes and to learn from them. Another key value of simulation is that experiences can be provided that are difficult to provide in the daily life of hospitals, such as a terrorist-created emergency, or that are critical but rare, such as dealing with life-support equipment that fails while in use.

The components of a simulation center vary from site to site but include most of the following: a suite of examination rooms and associated support spaces for learning with standardized patients or patient actors; a wet/dry room for practicing basic clinical procedures such as injections, catheterizations, suturing, and placing splints and casts; a simulated operating room, delivery room, ward room or examination room with one or more manikin-based patients; a room with computers for virtual worlds where students learn through role playing as physicians, nurses or other professionals; and a room for the use of task trainers such as laparoscopic surgery simulators or endoscopy/colonoscopy simulators.

Adequate support of a simulation center requires highly specialized staff. Technically skilled personnel are required to maintain the complex electro-mechanical systems that underlie manikin simulators or task trainers. Simulation programmers are needed to program scenarios for the manikins. Instructional designers are needed who understand how to create learning experiences using simulations, to achieve the desired learning objectives. Business managers maintain the fiscal soundness and stability of these expensive centers, determining the unique local potential for simulation-based learning and then making that need visible. Finally, trained faculty members are needed who understand how to teach with simulations and how to guide the activities and content development within the center.

### 23.5.4 Creating Learning Content

Technology-enabled learning content is now delivered across many platforms, ranging from the mobile phone and the tablet, through laptops and the Web, to physical manikins and game-like virtual worlds. However, the principles of such content development are unchanged and should use good instructional design principles. Instructional designers are specialists who can help formulate learning goals, offer suggestions for the design of instructional materials and tools to achieve those goals, design assessments and apply best practices from the educational research literature.

How to design efficient and effective educational software is the subject of a large number of books and other resources. Clark and Mayer (2011) provide practical application of e-learning principles, using findings from the educational research literature, and giving guidelines for selecting, designing, developing and evaluating educational software. They discuss important aspects of instructional design such as when and how to use media and text; how to facilitate collaborative learning with communication tools such as **chat** and **discussion boards**; how to help students build problem-solving skills; and how to use virtual coaches to improve learning. The design principles presented are also supported by research literature. Aldrich (2009) covers similar ground but with a focus on game and simulation-based learning. The ANSI/ADA Standard Guidelines for the Design of Educational Software (2006) from the **American National Standards Institute**'s (ANSI; see Chap. 7) Committee on Dental Informatics and the American Dental Association, offer a conceptual framework for quality assurance of educational software. As a framework, it is domain-neutral, does not restrict technical innovation, and leaves developers flexibility in design.

Creation of technology-enabled content can be labor intensive and time consuming and, hence, needs careful consideration. Three steps that should be considered are needs assessment, formative evaluation and summative evaluation, as described below.

**Needs assessment**: 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 discussion group to supplement the lectures or discussion sections? Would a central repository for course handouts reduce the load on departmental staff? This assumes that the necessary people and other resources are available. For example, are media of sufficient quality and comprehensiveness available, along with the necessary release of rights?

**Formative evaluation**: Prototyping, rapid iteration of development cycles, and formative evaluation are essential in creating a useful learning product. Because of the rich technology involved, frequently the intense focus on the technology brings a conviction that the resulting product will be useful. It is essential to test the early versions on real users and to listen carefully to their comments. Enthusiasm and positive feedback are not sufficient. The evaluation must answer the question whether users would actually use the product, as is, that same day on their own class. And if not, what is it that they would really use, and does this target keep moving each time they review the product.

**Summative evaluation**: Finally summative evaluation, after the product is in use, is valuable both to justify the completed project and to learn from one's mistakes. Table 23.2 provides an outline of the issues that can be considered in such an evaluation.

### 23.5.5 Standards for Learning Objects

The early interest in defining portions of learning modules as "learning objects" was to support reuse and repurposing of these components by institutions other than the developer institution, so as to justify the cost of content creation. For such sharing, standards had to be developed that allowed one object to be used by another software program. Groups active in such formalization include IMS Global Learning Consortium,[11] Advanced Distributed Learning,[12] and the IEEE Learning Technology Standards Committee.[13]

Even though a number of content collections and "education economies" developed, including some large collections such as MERLOT,[14] repurposing of individual learning objects did not develop into a major activity. On the other hand,

[11] http://www.imsglobal.org/background.html (Accessed 9/15/2013)
[12] http://www.adlnet.gov/overview (Accessed 9/15/2013)
[13] http://www.ieeeltsc.org:8080/Plone (Accessed 9/15/2013)
[14] taste.merlot.org (Accessed 9/15/13)

**Table 23.2** Criteria for summative evaluation of a technology-enabled learning product

| Criterion | Detail |
|---|---|
| System reliability | Does the system crash during the test? If yes, then measurement of usability or learning efficacy may be corrupted. |
| Content reviewed by subject matter experts | Content validity: Is the content appropriate for the target learner? Is it at the right level of complexity? Is it accurate? |
| Usability | Can the learner navigate through the content? Test this by setting tasks that require exercising all the interactive capabilities, and determine ease of use. |
| Validity | Face validity: Is the presentation of the material familiar and acceptable to the user? Construct validity: Does an expert perform better in this learning environment than a novice? |
| Learning efficacy | Does the user achieve the learning objective? |
| Curricular integration | The learning product may satisfy the criteria above, but is it embedded in the curriculum? If not, the likelihood of routine use is low. |
| Transfer to practice | Does use of this product cause measurable change in clinical practice? |

it did become important to be able to manage the learner's use of diverse learning objects, and to capture information about the learner's performance for storage in a learning management system. Therefore, a major use of standards became the definition of communications between client side content and a host system, typically the learning management system. The Sharable Content Object Reference Model (SCORM) is a collection of standards and specifications that supports exchange of information between the client and the host. SCORM also specifies a Package Interchange Format that defines how to transfer or move content when packaging it in a transferable ZIP file. More sophisticated information exchange, such as a method for defining the sequencing of content presentation, has been less widely used than the learning management system communication and the package transfer described above. SCORM is developed and maintained by the federal government through Advanced Distributed Learning (ADL).[15]

A health care-specific standards group is **MedBiquitous**, a consortium lead by Johns Hopkins Medicine.[16] Standards for communicating about individual accomplishments have been developed for reporting professional education and certification, tracking a learner's educational trajectory, exchanging a professional profile including training and certification data. At the system level, standards are under development for specification of competencies, and communicating evaluation data in health care education. For learning object authoring, specifications have been developed for learning object metadata, a SCORM version of the same, and a format for sharing virtual patient scenarios. All these specifications are eventually submitted to ANSI for ratification.

## 23.6 Future Directions and Challenges

As this chapter has shown, computers have played, and will continue to play, an increasingly important role in health sciences education. How will the rapid change and fluid nature of innovation influence how we use technology in education in the future? As we increasingly "digitize" almost all aspects of our lives, we can expect information technology to continue to weave itself more and more into the essential fabric of how we teach and learn.

How can computers help *advance* teaching and learning? Most faculty, even many of those who would consider themselves Luddites, have embraced, or at least accepted, technology's growing role in education. Students often have higher expectations of technology use than most health sciences schools can fulfill. How computers can help improve education is a key question of interest

[15] http://www.adlnet.gov (Accessed 1/8/2013)

[16] http://www.medbiq.org/about_us/mission/index.html (Accessed 1/8/2013)

to faculty and students alike. Most faculty members are keenly interested in finding out how technology can help them become better teachers. Most students, on the other hand, want to know how computers can help them learn more efficiently and effectively. Answering these questions requires research and development in a number of areas. We briefly discuss a few of those below:

1. As a number of commentators have pointed out, attempting to prove the superiority of educational software over traditional teaching methods is not only the wrong question, it is also methodologically impossible. The media-comparative approach used to do so is confounded by too many variables to be meaningful. Instead, we need to determine which computer-based interventions in education are the most effective given a particular context, goal and learner. Cook (2005) has proposed comparing educational software at three increasingly granular levels: (1) configuration, i.e. the "big picture" of how the software is used, for instance as a tutorial or to support small group learning; (2) instructional method, i.e. the techniques that support learning processes, such as questions, simulations and interactive models; and (3) presentation, i.e. the detailed attributes of how a particular instructional method is presented to the learner.
2. As Friedman (1994) has suggested, we should continue to identify which unique types of learning outcomes educational software can support. The simulation and 3D environments discussed above offer the opportunity to show biologic structures and processes from fundamentally different vantage points than previously possible. For instance, we can now travel inside a tooth and look outward, or compress the duration of a pathophysiological process from decades to minutes. We need to understand the effects of these novel ways of representing content on learners and how they understand it.
3. As described above, educational software holds enormous potential for replicating and even enhancing the experience of personal tutoring. However, despite years of research on intelligent tutoring systems, user models and adaptive testing, we have not yet developed a generalizable approach to computer-based tutoring in biomedicine. Progress in more basic domains, such as K-12 algebra, has been promising. It is to be hoped that health care education can produce similar advances over time.
4. "Just-in-time" learning, or learning integrated with clinical practice, is a clear need in an age when clinicians are expected to use best practices in caring for their patients under time constraints. Learning in the context of clinical care can leverage the clinician's motivation in a real-life situation, increasing the likelihood of a positive learning outcome. However, what approaches should be used to ensure that just-in-time learning is systematic, quantifiable and effective? Answering questions such as these is crucial as continuing competence of health care providers increases in importance.
5. Last, we should consider the information infrastructure for learning and professional development from the learner's perspective. At present, the materials that learners either receive or produce during their education vary in content, format and platform. For instance, course syllabi, slide presentations, electronic books and papers, course discussion list and blogs, and list of references typically exist in different places, with different constraints on accessibility. The fact that most materials can be "tied together" through the Web interface of a learning management system is scant consolation. The simple fact is that it is difficult, if not impossible, for most learners to create and maintain a comprehensive and organized portfolio of their learning materials as it was possible in the paper world. With regard to education, we need to elevate the user-centered design philosophy discussed in Chap. 5 to the systems level. Doing so will help maintain learners create, maintain and enhance their personalized store of learning experiences in a systematic, easy-to-use and predictable way.

The listed research questions and considerations are only a small selection of the interesting challenges of educational research in biomedicine. Journals such as Academic

Medicine and the Journal of Educational Research periodically discuss these and other challenges in more depth.

## 23.7 Conclusion

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

## Suggested Readings


AAMC Institute for Improving Medical Education. (2007, March). Washington, D. C.: American Association of Medical Colleges. https://members.aamc.org/eweb/upload/Effective%20Use%20of%20Educational.pdf *Effective use of educational technology in medical education. Colloquium on educational technology: Recommendations and guidelines for medical educators*. This report summarizes the discussion of an expert panel on the documented efficacy of educational technologies in the curriculum.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind experience and school*. Washington, D.C.: The National Academies Press. This National Research Council book synthesizes many findings on the science of learning, and explains how these insights can be applied to actual practice in teaching and learning.

Cook, D. A. (2005). The research we still are not doing: An agenda for the study of computer-based learning. *Acad Med, 80*(6), 541–548. Cook reviews the progress (or lack thereof) on Friedman's proposed directions for educational software research, and suggests strategies for meaningful comparisons in computer-based instructional design. He discusses additional research challenges, such as adaptation to individual learners, just-in time learning and simulation.

Crowley, R. S., Legowski, E., Medvedeva, O. M., Tseytlin, E., Roh, E., & Jukic, D. (2007). *Evaluation of an Intelligent Tutoring System in Pathology: Effects of External Representation on Performance JAMIA, 14*(2), 182–190. Crowley describes a study that evaluated SlideTutor with physicians in two academic pathology programs. On average, students improved their diagnostic and reporting performance by a factor of four after as little as four hours of use of the system.

Eliot C. R., Woolf B. P. (1996). An intelligent learning environment for advanced cardiac life support. Proceedings of the AMIA Annual Fall Symposium, Washington, DC, pp.7–11.

Gaba, D. M. (2004). The future vision of simulation in health care. *Qual Saf Health Care, 13*(Suppl 1), i2–i10. Gaba describes the range of technologies and methods available for simulation-based learning.

Kirkpatrick, D. L. (1994). *Evaluating training programs*. San Francisco: Berrett-Koehler. This book presents a multilevel system for evaluating training programs.

Rall, M., Gaba, D. M., Dieckmann, P., & Eich, C. (2010). Chapter 7: Patient simulation. In R. D. Miller (Ed.), *Anesthesia* (7th ed.). Philadelphia: Churchill Livingstone Elsevier. The authors summarize the history and current uses of manikin-based simulation, the most common type of simulation in use for clinical teaching.


**Questions for Discussion**

1. In developing effective educational interventions, you are often faced with a choice of instructional methods. Which of the instructional methods listed below would best match the instructional goals listed? Please justify your selection.

Instructional goal

1. Ability to intubate an unconscious patient
2. Memorize the terminology used in neuroanatomy
3. Recognize the symptoms of a patient with probable mental illness
4. Learn the pathophysiology of hypertension
5. Detect histopathologic variations on histology slides

Instructional method

1. Case-based scenarios that include video
2. Physical simulation with computer-based feedback
3. Didactic material that includes text, images and illustrations
4. Intelligent tutoring system
5. Drill-and-practice program

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 with a physical "mannequin" whose 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. 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 sub-concepts 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.
4. You are a junior faculty member at a major medical center and you just were appointed director for a course on clinical patient examinations. You decide to check out several sharing sites for curricular material, such as MedEdPortal, to try to find relevant teaching materials. What kind of issues/problems would you expect in integrating material from those sites in your course?