Computer-Assisted Learning: cyberPatient™—A Step in the Future of Surgical Education

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ABSTRACT Computer-assisted learning is a hot topic and is evolving parallel with the rapidly growing computer technology. Today, modern computers with sophisticated software are able to create a new dimension in the application of many important pedagogical principles and philosophies. Modern computers with excellent multimedia applications are capable of simulating a realistic situation that enriches the educational environment, improves the learning process, and brings new challenges to the process of “learning by doing.” The use of computers in medical industry and in medical education lags far behind other applications in the industrial world. Although a great many computer-assisted learning programs have been developed in the last decade and patient simulation has been attempted, there are no computer programs in the market that are capable of simulating the realism of the patient–doctor relationship. cyberActive Technology Ltd. has been able to complete this mission. The computer software cyberPatient™ developed by cyberActive Technology Ltd. is able to realize this long-term dream of medical students and educators. The discrepancy between theoretical and practical medical knowledge in the classical medical education was greater than in any other aspect of science. In classical medical education, diseases were taught beginning with etiology and pathogenesis to signs and symptoms. In practice, the patient comes to the doctor with complaints, and the doctor has to think backward to find out about the etiology and pathogenesis. This discrepancy created enormous difficulties for interns and young doctors with respect to the application of theoretical medicine to medical practice. This was one of the reasons why medical schools turned to a new problem-based learning curriculum. The new curriculum, however, has brought new challenges and problems of its own. Some of the problems include patient availability, increased demands for teachers, and, in turn, significant increases in the costs of medical education. Intensive use of computers may be a solution for problem-based learning. The aim of this article is to give an overview of computer-based learning and its place in the future of medical education.
KEYWORDS  computers, cyberPatient™, medical education

The Chinese can be accredited as the first to have created a computational device, which is known as the abacus. The abacus, much like the modern computer, was first created to aid an emperor’s treasurer in calculating how much grain his subjects produced. Eventually, the abacus became a teaching tool. Today it is still used widely in the East as an educational tool to teach elementary school children how to perform simple math quickly. Based on the mathematical skills that these children achieve at such young age with the help of the abacus, it can be said that the abacus is a very successful teaching tool. When computers were first invented, they were basically advanced calculators. Today, computers are used mainly for storage and manipulation of data. Modern computers are on the verge of the same transition as the abacus, from a calculating tool to a learning tool. The reason this transition is happening now and not in the 1970s and 1980s is due to the fact that computers have become easier to use, less expensive, and faster, all at the same time. The ease of use came with the advent of the graphic user interface (GUI) first developed in the Xerox PARC (Palo Alto Research Center) labs in 1970s and then widely made available with Macintosh computers in 1984. Introduction of Windows by Microsoft made the graphic interface available for IBM computers. The invention of the personal computer (PC) by IBM on one hand and breakthroughs in the manufacturing process on the other hand have made computers available to more and more people worldwide and hence brought the prices down. Due to the very competitive and innovative computer world, desktop computers are now faster and smaller than the heavy-duty mainframe computers that were available in the 1970s. Rapid growth and advances in software and hardware technology provided the opportunity for educators to use computers as a learning tool in the educational environment.

COMPUTERS: A LEARNING TOOL IN EDUCATION

Even in 1950, Skinner [1] and colleagues saw, in technology, the potential for great improvement in educational methods. Since the “Skinner box” could provide the controlled and predictable environment required to teach pigeons and rats, the possibility of a “teaching machine” that could carry similar functions for teaching children looked promising. Skinner’s early machine consisted of a frame that presented a single unit of study materials from which certain figures or letters were missing. The student had to supply the missing element. The student was not able to turn the crank for the appearance of the next item if the previous answer was wrong. Evaluation of “teaching machines” in comparison to conventional teaching usually showed significant advantages for machine instruction; however, they were subject to methodological limitations [2]. Therefore, by the mid 1960s, “teaching machines” had begun to be disregarded due to their limited scope and poor results.

In the mid 1960s, the “teaching machines” were replaced by computers entirely. The idea of computer-assisted instruction (CAI) became a popular concept in educational circles. This new concept dictated that computers should assist the teacher in achieving an instructional goal. CAI offered an individualized instruction geared to each learner’s level and pace. CAI software typically placed heavy reliance upon drill and practices. From elementary-school skills in arithmetic and spelling to university skills in statistics and psychology, instruction was carried out with CAI programs. Today, these types of programs are still in favor for children under 9 years of age [3]. Evaluations of CAI in comparison to the conventional methods of teaching were widely conducted in the 1980s. Niemiec and Walberg [4], as well as many other investigators, demonstrated CAI to be at least moderately more effective compared with traditional techniques. Advancement of computer technology and the availability of microcomputers in the 1980s brought a new concept to the attention of educators. This included the development of intelligent tutoring systems (ITS). These types of programs take into
account the pattern of errors made by an individual student over time and use this information to build a reasoning model for the education of the student. Although the role of ITS is controversial in educational circles [5, 6], it has yet to be demonstrated that an ITS is necessarily more effective in practice than an “unintelligent” tutoring program. Studies for the evaluation of such programs and cooperative analysis have not been performed.

In the 1990s, computer simulation and multimedia presentation are rapidly replacing older educational tools and bringing more sophisticated educational methods that involve the most important philosophies and theories in educational psychology. Predictions were made that computers would affect all areas of education by the turn of the century [7].

**PEDAGOGICAL PHILOSOPHY**

Ironically, computer technology coincides with the peak of Piagetian influence in developmental psychology and the psychology of education. Piaget’s pedagogical philosophy dictates that learning is secondary to and dependent upon progressive reorganization of the cognitive functioning. To educate is not to “shape behavior” but to provide the conditions in which students themselves can construct an understanding of the material given to them. Thus, the role of the teacher becomes essentially facilitatory, providing a suitable environment, the resources, and the encouragement for student creative explorations. This educational philosophy became one of the foundations for the new problem-based/self-directed curriculum in most North American medical schools.

Papert, in the late 1970s, initiated the integration of Piagetian educational philosophy into the development of computer assisted learning. In his words [8, 9], the potential of computers should not be considered as surrogate teachers controlling students learning. Computers should enrich the learning environment by expanding the students control over their self-learning. Papert introduced a programming language called logo. The value of logo evaluated by independent investigators is controversial. Pea and Kurland [10] found no systematic evidence for significant improvement in problem solving compared to other settings. De Corte, Verschaffel, and Schrooten [11] showed the usefulness of logo as a learning tool in a highly structured curriculum. The effectiveness of logo in specific subjects such as mathematics, geometry, and others is undeniable. The advancement of computer hardware and software in the 1990s created powerful authoring tools that allowed students to create complex multimedia programs relatively easy. This new environment generated the idea for the use of simulators in education.

The philosophy of “see one, do one, teach one” has been part of the medical education of residents for a long time. Undergraduate medical programs, however, have practiced the “chalk and talk” philosophy supported by workbooks until recently. The new problem-based, case-based curricula in North American medical schools adopted the Piagetian educational philosophy of “learning by doing.” Schank and Cleary [12] shared this philosophy of “learning by doing” with Papert and Piaget and proposed the use of computer simulation in all educational aspects of life for application of the philosophy of learning by doing. Computer simulations are used as teaching tools in disciplines outside of medicine. A good example of the successful application of computer simulation is the flight simulator designed to train pilots. Schank and Cleary used computerized, simulated trips around the United States by car. Using this simulator, they came to the conclusion that students’ scores on conventional geography tests improved significantly for weak students and slightly for strong students. Computer simulation not only considers the philosophy of “learning by doing” but also makes the learning process highly motivating and fun. In addition, computer simulation makes the learning process risk free and less costly as compared to programs using medical subjects.

The one important criticism of the computer-assisted learning strategy is the isolation of the individual from social interaction and a collaborative learning environment. This theory of “social constructivism” proposed by Vygotsky criticizes not only the computer-assisted learning but also the “constructivism” theory of Piaget. Paul Light [13] indicates that while sharing many of Piaget’s ideas about cognitive development as an active process of construction, Vygotsky envisioned such construction as an essentially
Invited Review

Computer-assisted learning is a new area of growth and will reach its peak within the next few years [16–18].

COMPUTERS IN MEDICAL EDUCATION

Traditionally, computers in medicine have dominated data processing in hospitals; this is known as medical informatics. Medical informatics deals with manipulation of the vast amounts of data that pass through hospitals and clinics daily. This information can be anything from billing to the storage of patient diagnostic tests.

The development of computer programming in medical education has taken two directions. One direction is the development of online curricula and tests, and the second direction is the development of interactive computer simulators. Good examples of the first direction are programs developed for teaching clinical pharmacology and therapeutics at the Department of Medicine, University of Pittsburgh [19], and the PsyCLe project [20]. The latter was developed in the United Kingdom around an ambitious program called Teaching and Learning Technology Programs (TLTP). The University of York and the University of Sheffield lead this project with eight content modules covering auditory perception, visual perception, developmental psychology, social psychology, statistics, experimental design, memory, and philosophical roots, plus a generic concept mapping model.

The development of computer simulation has also taken distinct directions. All too often, “shovelware” is produced in the authoring of medical educational titles. “Shovelware” is a term used to describe a computer product such as a CD-ROM that is ported directly from a book. Basically, these are typed pages with links to a medical dictionary, text searching, video clips, and audio clips. Although these titles might be great multimedia products, they are not interactive. These CD-ROMs usually help sell a book when the unsuspecting shopper is deciding between two different books. After purchasing the book, one realizes that it is easier to open the book for quick reference rather than to boot up the computer, put the CD-ROM in the tray, start the program (if it is compatible with the operating system), and then try to read print on the computer screen. After some time, the novelty of CD-ROM “shovelware” titles wears out. Nevertheless, many investigators believe that currently designed interactive software is as good, if not better, than the traditional method of learning [4, 21, 22]. The question of the superiority of computer-assisted learning over the traditional methods has been controversial. Niemiec and Walberg believe [23] that computer-assisted learning is a more effective learning medium than traditional instructional methods. They came to this conclusion by performing a comprehensive review of 551 studies between 1969 and 1985. Superiority of computer-based learning has also been confirmed by others [23]. However, Clark [24] is highly critical of the superiority of computer-assisted learning. He consistently promotes the idea that no one medium (including computers) has any distinct advantage over any other [24–27]. Clark’s conclusion was also supported by others [28]. The controversies surrounding this subject were disputable in the early stages of computer programming and use of multimedia. Recently, Simpson [29] strongly criticized Clark for non-discriminative approaches to learning mediums. Ottaviani [30] actually demonstrated in a series of experiments that multimedia format with voice and pictures can significantly improve the learning process as well as the retention of knowledge. It is obvious from this discussion that a high level of interactivity in a multimedia environment will greatly improve the outcome of the learning process.

To learn more about the secret of interactivity, we have to go back and learn a little bit more from the abacus. What really makes the abacus great is “active learning.” The abacus is a visualization of numbers.
Using the abacus, one is not able to write formulas or numbers on paper but one actually looks at the beads and slides them with one’s finger. In the new medical curriculum adopted at many medical schools in North America, the emphasis is on getting the medical student in contact with patients as soon as possible in order to provide an active learning environment for self-motivation, in addition to problem-based learning philosophy. Some excellent interactive computer programs such as breath sounds or heart sounds, where the student is asked to listen to these sounds and then to pick out the abnormal sound, are already implemented in medical education. Although these programs are simple examples of what is to come, they are essential stepping stones in bringing together interactivity and medical education. Interactive computer programs can take the new medical school curriculum one step further through technologies like cyberPatient™ (CP). CP is an interactive problem-based method of teaching that has the potential of guiding students through the management of patients with a variety of pathological conditions as they happen in real life. Picture a doctor operating on a patient when suddenly a complication arises and due to the doctor’s inexperience the patient dies. How fortunate would it be if the doctor’s mistake happened in cyberspace with cyberPatient™ and the inexperienced doctor simply restarted the operation with a click of the mouse. With CP, a medical student can log in hundreds of hours of operating room time without actually setting foot in the operating room, and can also observe hundreds of cases that the student may not otherwise see in his or her entire life.

Of course, simulations will never take the place of real experience. It is reasonable to argue that the real exposure of medical students to patients can never be replaced by a computer simulator, but there are several problems that medical schools face in bringing students and patients together. Firstly, there is a patient availability problem in many hospitals. A medical school of a hundred students has no way of finding the perfect patient with the required specific disease for every single student or even a group of students. This problem has been compounded by the drastic reduction in the number of acute care hospital beds. Very few patients are admitted to the hospital prior to surgery, and hospital stays after surgery are getting shorter and shorter. Thus, there are very few patients in hospitals who have physical signs of disease and are well enough to be interviewed by a medical student. Second, there are not enough medical professors to expose any one patient to every single student or group of students, especially with inexperienced medical students who need extra supervision. Third, if a school were to proceed with a problem like this, tuition costs would skyrocket and the number of students enrolled might have to be decreased. Thus, it is expected that the new curriculum may significantly increase the cost of medical education, primarily due to patient availability and tutorial time. One may argue, therefore, that it is necessary to have human simulations for availability and effectiveness. An alternative human simulation program for teaching medicine available at the present time is Objective Structural Clinical Examinations (OSCE), which are extremely expensive. The main obstacles around human simulation are the costs of training actors and then paying them to be the subject of an examination by a student. At the present time, the cost of patient simulation and OSCE's for medical schools is between $100,000 and $200,000 per year. This cost does not consider the time of the professors, administrative costs, and the extremely difficult organizational cost of the program. In addition, with this budget, medical schools are able to provide patient simulation sessions only twice in the 4 years of medical school. Computers, on the other hand, could assist a great deal in bringing the ideal teaching environment into existence. Think of each computer as a personal tutor who never gets tired of answering questions and is capable of providing a patient of choice to students at a convenient time and place. We believe that with the right program running on the computer, the quality of medical education can be improved substantially in the future without raising the cost of medical education. The Association for Surgical Education has recognized these issues and has formed a committee with the specific task of adopting interactive computer tools in medical education.
PRODUCTS AVAILABLE

At this time, three main categories of medical education software are emerging. The first category consists of multimedia products that merely duplicate textbook information and paper-based testing processes and add little value to the education process. Examples in this category include CD-ROM versions of established medical reference books, such as Harrison’s *Principles of Internal Medicine* (McGraw-Hill).

The second category of medical education software consists of more dynamic representations of traditional reference information. The leaders in this market are A.D.A.M. Software, Inc., and Novartis Pharmaceuticals, which produces *Netters Interactive Atlas of Human Anatomy*. These products enable students to peel away different layers of skin and tissue to allow an in-depth view of anatomy. Although these products may make learning more interesting, they do not enable the student to develop any diagnostic skills.

The third category, in which cyberActive Technology Ltd. is believed to have created a breakthrough innovation, consists of products that actually simulate the doctor–patient experience. The closest competitors provide software products that present text-based cases to the user and prompt the user to determine a diagnosis and treatment plan. While these products do encourage students to consider diagnostic alternatives, they typically present examination findings, rather than forcing the student to complete the medical exam, determine the appropriate ancillary tests, draw a diagnostic conclusion, recommend a treatment plan, and, when necessary, conduct a surgical procedure.

Competitors in this third category include A.D.A.M.’s Iliad and Novartis’s DxR. Both of these programs, while more sophisticated than the previous generation of medical software products, are cumbersome to use, difficult to learn, and do not realistically simulate a patient–physician encounter. The interface is text based, and the presentation of information on the screen is cluttered and difficult to assimilate. Furthermore, neither of these programs enables the student to perform surgery and other interventional procedures on the virtual patient.

**CYBERPATIENT™**

cyberPatient™ is a revolutionary interactive multimedia tool that will fundamentally change the way medical educators teach and the way students learn (Figure 1). It is a visually appealing software program that invites students to examine, diagnose, and operate on virtual patients and provides them with feedback on their performance. Just as a pilot trains to fly an airplane on a flight simulator, a medical student can practice on many virtual patients before ever treating a real patient.

cyberPatient™ will be released online; students will be able to access the entire archive of cases. Cases will be available with increasing degrees of difficulty, so that students can revisit cases they covered in an earlier year of their training and study more advanced aspects of diagnosis and treatment for that particular disease.

cyberPatient™ has been designed to simulate the doctor–patient interaction as closely as possible. In so doing, the following interaction elements are enabled:

- Patient history. A major aspect of medical education is learning to gather data from patients by asking them appropriate, pertinent questions. Learning to take a good patient history is crucial, as it is during this process that the physician develops a mental list of potential diagnoses that he or she will pursue further with a physical examination and ancillary tests. cyberPatient™ builds students’ history-taking skills by urging users to ask thoughtful questions to which the virtual patient responds. The virtual patients’ responses not only are realistic, but are also complemented by appropriate movements and facial expression (Figure 2).

- Physical examination. cyberPatient™ offers an excellent “foot-of-the-bed” observation capability, which is very important in medicine. After noting the virtual patient’s general appearance, the user is able to take the patient’s vital signs. Close-up observation is possible with the use of numerous instruments, including ophthalmoscopes, otoscopes, tongue depressors, sigmoidoscopes, stethoscopes, and more. When users opt to use
FIGURE 1  cyberPatient™ splashscreen.

FIGURE 2  History taking: personal history.
a stethoscope, for example, actual heart sounds, breath sounds, and bowel sounds are projected through the computer’s sound system. Unlike any other medical software, cyberPatient™ enables users to palpate the virtual patient to check for tumors, lymph node enlargement, or other abnormalities (Figure 3).

- Ancillary tests. A state-of-the-art laboratory is accessible to the user for further delineation of diagnoses created from history taking and physical examination. The user has a choice of test options, and the program will keep track of appropriateness of order and type of test. Complex blood tests, electrocardiograms (EKGs), x-rays, angiograms, and computed tomography (CT) and magnetic resonance (MR) scans are all available to the user. Results are reported immediately to assist with diagnosis (Figure 4).

- Diagnosis development. The user is required to present a single diagnosis to the on-board chief surgeon or physician following his or her interaction with the virtual patient. He or she may be given immediate or delayed feedback on the conclusion, depending on the purpose of that product version.

- Treatment planning. The user will be required to outline a treatment plan. Subsequent responses from the patient will be recorded and follow-up visits may be included. Alternatively, surgery may be required as part of the treatment, in which case the chief surgeon will prompt the user to proceed to surgery.

- Surgery. In cases where surgery is required, the user will take the virtual patient to the operating room and carry out a virtual surgical procedure. The steps required must be chosen by the user, including order and instrumentation. Efficiency of the surgical procedure will be recorded by the program (Figure 5).

- Postoperative management. In those cases where surgery of the virtual patient is required, an opportunity for postoperative management will be provided. In addition, the user will be required to plan in-hospital and discharge orders (Figure 6).

- Follow-up. A simulation of 6-month, 1-year, 2-year, and 5-year follow-up for each case is programmed with each cyberPatient™ case. This is important for learning about the prognosis of the patient.

![FIGURE 3](image3.png)  
**FIGURE 3** Physical examination: deep palpation of the abdomen.
cyberPatient™, as an interactive educational tool, has unique features that enable it to meet the needs of the educational environment:

1. Practical approach to medical education. cyberPatient™ adopts the Piagetian philosophy of learning by doing. It provides high quality medical content in a problem-based or case-based fashion. The netcentric character of this software makes it compatible with Vygotsky’s theory of social constructivism.

2. An on-board professor that provides feedback. Depending upon the level of the student, an on-board professor may provide immediate feedback.

FIGURE 4 Lab tests: x-ray.

FIGURE 5 Surgery: exposure and dissection.
FIGURE 6  Postoperative care.

when required. In more advanced cases, comments may be accumulated and provided to the user at the completion of each case or perhaps following the “death” of a virtual patient. The on-board professor may provide recommendations to the user based on his or her performance during the case, including suggested readings.

3. Tracking responses. The efficiency and correctness of choices made by the user are measured and recorded by the cyberPatient™ software. This may be used not only for feedback to the user, but also to track performance for examination purposes. In the end of each case, the program will print out specific comments and general statistical data about the performance of the student.

4. Tracking costs. Along with clinical efficacy, cyberPatient™ will track expenses incurred from laboratory and treatment options so that the user’s economic efficiency can be reviewed.

In preliminary demonstrations, cyberPatient™ has been remarkably well received by the medical community. A media review of the product was recently published in the Journal of Investigative Surgery.

During 1998, cyberPatient™ was presented at the Association for Surgical Education and was showcased at the Slice of Life and Computers in Health-care Education Symposium, an annual international conference providing a forum for exchanging new ideas in health sciences education and reviewing state-of-the-art computer technology.

cyberPatient™ was accepted for presentation as a computer-based learning tool at the Academy of Surgical Research meeting in Scottsdale, AZ, in September 1999.

In summary, computer-assisted learning is able to solve problems created with the new curriculum and may improve the quality of our medical graduates. An international multicenter trial is being organized at this time to evaluate the effectiveness of computer-assisted learning in comparison to traditional textbook learning. This project is being organized by the University of British Columbia and will be performed in 12 medical schools around the globe in the next year.

REFERENCES
