Viewpoint ■

Information Technology and Medical Education

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Editor's note: G. Octo Barnett presented the second American College of Medical Informatics (ACMI) Distinguished Lecture at the American Association for Medical Systems and Informatics (AAMSI) Congress in May 1989. The first three lectures were not captured in printed form at the time of their presentation. The lecturers have generously reconstructed their presentations, and this is the second of the series to appear in the Journal.—*W.W.S.*

The topic of this lecture is a review of the present status of the use of information technology in medical education. I frame this presentation in a somewhat forced metaphor of medical education as a disease state and describe the signs and symptoms, the etiology, the complications, the possible treatments, and the expected outcome. Because the disease is described in its most advanced state, I occasionally oversimplify and sometimes exaggerate for the purposes of illustration and emphasis.

Before I begin, I have a few personal remarks to make. First, I want to acknowledge that much of the work included in this presentation reflects the contributions of colleagues, postdoctoral fellows, and students with whom I have worked over the years. I am deeply indebted to Dean Dan Tosteson and the faculty and administration of Harvard Medical School for their leadership and support in generating a new vision of medical education. Second, I want to express my gratitude to many of you in the audience with whom I have shared years of fellowship and professional collaboration and from whom I have borrowed many good ideas. One of the most enjoyable and rewarding characteristics of medical informatics is the comradeship and mutual sharing that is prevalent. And third, little of the content of this presentation is unique. Much of what we at Harvard Medical School have tried to accomplish in the use of computer technology in medical education builds on the work of many other groups and institutions. The only unequivocal claim I can make about our contributions is that we have tried to steal only the best ideas.

Let us consider the diagnosis of the disease condition of medical education by first reviewing the signs and symptoms. One of the most apparent symptoms is that medical students are rejecting the current lecture-based method of education. Prior to the curriculum reforms at Harvard Medical School known as the New Pathway, the three to five lectures each day were very poorly attended, and those students who did attend exhibited evidence of severe sleep deprivation. Most medical students have a liberal arts background, which means they are used to a large amount of independent study. The students felt that the didactic passive educational strategy was neither appropriate nor acceptable and therefore deemed that the lectures were not worthy of their participation.

Another symptom of the disease condition is that medical students have considerable difficulty integrating the material included in the first two years of basic science with the material included in the last two years, where the focus is on clinical medicine. In part this is due to the shift in emphasis and style of content that marks the transition, and in part it is related to the fact that in the first two years the faculty focus on teaching the discipline-specific information and give less attention to relating the information to other medical fields or to a disease context. There is often little integration of the content in the different disciplines to provide a coherent approach to problem solving in clinical practice.

A more disturbing symptom is that we are graduating

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physicians who rapidly become outdated in fields other than their own specialty. Graduate training and practice tend to focus on smaller and smaller parts of human anatomy and physiology, resulting in less breadth of the disease spectrum. The emphasis on specialization is a natural human tendency when the measure of competency is factual recall. These symptoms of the disease in medical education are now becoming critical as medical education is challenged to place more emphasis on primary care and less on super-specialties.

The most critical symptom is that medical education does not provide sufficient emphasis on the student's acquisition of commitment and skills to become a lifelong learner. Too frequently, medical school faculty fail to give appropriate emphasis to the reality that the educational experience of medical school must be just the beginning of a lifelong concern. To assume that the scientific content learned by a student during medical school will be adequate and appropriate for the remainder of the student's career is preposterous. The simple act of graduation from medical school does not qualify the student to be a good physician for the rest of his or her life.

The etiology of the usual form of the medical education disease state is in large part the "information explosion" in medical knowledge. The quantity and complexity of new scientific knowledge in the basic medical sciences and in the development of new methods for the diagnosis and treatment of illness makes it a formidable task to keep abreast of the medical knowledge base. This rapid expansion of knowledge has placed impossible time demands on the curriculum. Indeed, many students would paraphrase the words from Hippocrates, which are carved in stone on one of the walls in the Harvard Medical School quadrangle, as "Life is short, the art long, occasion instant, experiment perilous, decision difficult." Given the state of medical education today, the medical student would add "books innumerable, journals countless, lectures endless."

It is estimated that over six hundred thousand articles are published in the biomedical literature each year. If a student attempted to keep up with the literature by reading two articles per day, in one year this conscientious individual would be over 800 years behind. The perception of the typical student is that trying to keep up with faculty expectations is like the sorcerer's apprentice's trying to keep the floor dry. Increasing the duration of professional education is not practical; increasing the fragmentation that results from narrow specialization is not wise; and depending on continuing education to fill the gap will not work.

A second important component of the etiology is that medical education is a strongly tradition-oriented environment and is very resistant to change. For centuries, medical education has been almost completely based on lectures, in large part because of a dominant concern with factual recall. Education by lecturing uses a well-defined approach. Lecturing material can be used repeatedly. Assessing the student's acquisition of factual content is easy and decisive with lecturing. The weakness of this strategy is the dominant concern with short-term memory and factual recall. A primary strategy of the successful student is to focus on intense acquisition of large amounts of factual material, regurgitate the material on the multiple-choice test that follows that block of material, and then quickly forget the material so that complete attention can be given to new material. The tests offered by the National Board of Medical Examiners are too often based on the factual minutia of medicine, because such tests are the easiest to develop and to standardize. Too often, the ability to recall factual minutia has been standardized as the most effective strategy to discriminate between the good student and the poor student.

A third etiologic element is that the medical curriculum is dominated by departmental organization. Each department owns a certain block of time, and uses its time by teaching the specialized subject matter of the department. Any modification by the curriculum committee is a process of negotiation (e.g., which department should be given two extra lectures, or which course must be shortened by three days?). A related factor is that for reasons of funding and scientific specialization, most of the senior faculty in medical schools are selected on the basis of research contributions, not on educational leadership or ability to teach. Many medical schools are in effect research establishments that have an ancillary medical school.

The fourth source of concern in medical education is the changing nature of the practice of medicine with the rapid metamorphosis of hospital-based practice to ambulatory practice. Because of rapidly changing reimbursement patterns, hospital length of stays are decreasing, hospitalization is occurring only for acute serious conditions, and more and more medical care for common diseases is being shifted to the ambulatory clinic or to ambulatory surgery. These shifts in medical practice have been associated with a decrease in faculty and resident time available for teaching medical students in the classic apprenticeship mode in a hospital environment.

The last element of the etiology of the disease in medical education is the failure to appreciate that medical students are adults and learn more effec-

tively when considered adults. Many educational approaches in the medical curriculum are dominated by rigid presentations of a subject and rote learning strategies. We often fail to appreciate that the educational opportunities and strategies for adult education are significantly different from those for elementary education.

The treatment of the disease in medical education requires a number of curriculum changes and changes in the priorities of medical schools. In this presentation, I focus only on a proposed treatment using information technology. I chose this focus not because I think it is the most important, but because it is the area with which I have the greatest experience and familiarity. Although I may tend to wax enthusiastic about the use of computers in medical education, I provide a necessary FDA-like warning about the limitations and possible side effects of the proposed treatment.

First, computers can never be substituted for good teachers. A critical role of a teacher in medical education is to provide context for the medical content and enthusiasm for the importance of the subject matter. Additionally, the good teacher serves as a role model for dealing with the complexity and the scientific interrelationships of the content, as well as for demonstrating the problem-solving skills required in the practice of medicine. Please do not infer from this presentation that I am advocating an isolated sterile room with computers along the wall as constituting a medical school.

Second, I am not proposing that information technology will completely replace books and lectures. Books will have a continuing role in being more familiar, more portable, and easier to browse. Lectures and conferences will have a continuing role as an opportunity for the student to interact with an exceptional teacher who can provide a much more inspiring and entertaining presentation than can any computer.

Despite my enthusiasm for this treatment, there is no quick cure in the proposed use of computers in medical education. We have just begun to exploit the potential of information technology, and much of this presentation must be framed in the future tense, as a vision of what can be, rather than as a description of what is. In addition, I must warn you that much of what I propose as treatment was attempted in the last decade in a variety of institutions. Some of these technologic advances have been innovative and promising, but few have persisted beyond an initial experimental stage. A literature review of the use of information technology could lead one to expect that there is widespread application of computer-based medical educational programs in many medical schools. However, such an inference would be untrue; there has been little impact of information technology in the treatment of the diseases of medical education.

There are several reasons for this limited effect of information technology: the primitive nature of the early display devices and computer interfaces, the financial cost of the equipment and personnel time required for the development of the educational programs, and the difficulty of integrating a new technology into the standard medical school curriculum. An additional reason for the lack of progress was the rather simplistic technologic strategies used in much of the early work. It is easiest to write computer-based educational programs that are simple page-turners with student interaction limited to multiple-choice questions. This strategy is not that much different from what can be accomplished with a book. One lesson learned many times over is not to use the computer to replace a book. A book is much cheaper, much more portable, and much easier to underline.

Despite the simplistic nature of some of the past applications of information technology, I am excited about many of the computer-based educational programs that have recently been developed. The introduction of the personal computer has made it possible for a single faculty member or a small group to start a program using information technology for a single course. Compared with even five years ago, the computer technology is less expensive, the computer power is much greater, and the graphic displays and visual interfaces are much improved. It is no longer necessary to have a large budget to begin to experiment with the use of computer technology in medical education. In addition, it is my impression that more and more medical schools are becoming concerned about the deficiencies of current medical education and are supporting a variety of innovations. Despite the lack of universal support from medical school faculty, and the lack of adequate financial resources, there has been significant progress in developing new programs in medical education in the last few years.

Additionally, students now coming into medical school are knowledgeable computer users and are usually more experienced in the use of information technology than are most of their teachers. These students are critical of medical schools that do not provide a level of computer-based educational applications similar to that provided in their premedical training. This demand from the students is an effective force

to stimulate the medical school administration and faculty to provide resources to develop educational applications using information technology.

Let us now consider specific components of the treatment plan. One of the earliest and most important of information technology applications was computer-assisted access to bibliographic literature. I argue that every medical student should develop a good understanding of and have extensive experience with the use of MEDLINE. Maintaining a current awareness of the medical literature is essential to the effective practice of medicine. The extensive variety of commercial computer applications that have taken advantage of the National Library of Medicine (NLM) database have been important stimuli to minimize the technical problems in using MEDLINE. Of particular importance have been the development of "user-friendly" interfaces (such as Grateful Med, PaperChase, etc.), the distribution of the databases on CD-ROM, and the use of the Internet as a method of access.

The use of computer-supported access to the medical literature has given emphasis to the usefulness of a structured vocabulary with a controlled terminology. A scientific discipline requires an agreed upon nomenclature of discourse, and the Medical Subject Headings (MESH) vocabulary developed by the NLM has been of fundamental importance in providing the foundation for such a nomenclature. The recent effort sponsored by the NLM in developing a Unified Medical Language System as the basis for a comprehensive clinical vocabulary will undoubtedly be important in the further application of information technology in both medical education and medical care.

Two computer applications that have important roles but that are only indirectly related to medical content are word processing and electronic mail. An important aspect of medical practice is creating documents, particularly patient medical records. The replacement of the handwritten student report by a word-processed document leads to a much more legible and organized presentation of the patient's clinical status, and to a document that better supports a comprehensive faculty critique. The availability of electronic mail plays an important role in supporting rapid communication between students and between faculty and students; this communication can be very helpful in cultivating a sense of community among individuals who do not live or work in the same building and who would otherwise not have extensive contact.

A key feature of medical education is the acquisition of an immense quantity of factual content in areas ranging from biochemistry to epidemiology to descriptions of disease states and their treatments. The standard method of acquisition of this content is by the student's reading and creating notebooks filled with outlines, lecture notes, diagrams, and "pearls." One of the potentially valuable uses of information technology is applications that support the recording, indexing, and retrieval of this medical content. The challenge is to provide the factual information in a format that takes full advantage of the graphic nature of much of the information and that allows the student to follow a single thread of inquiry across disciplines such as microscopic anatomy, physiology, pharmacology, and radiology. An important characteristic of such a computer-based compendium of medical content is that it must be comprehensively indexed, not just by words or chapter headings, but by medical concepts relevant to specific medical problems. A computer-based personal reference file that integrates the medical content provided by the faculty with the personal notes of the student would be a vastly superior resource for continuing education, particularly if it were indexed in such a way that links to content in the published literature could be easily made.

The format of the computer-based content is critical. To transform content from a textbook to a computer file or a CD-ROM with no change in format gives little added value, other than a faster way to turn the pages. There must be a powerful capability to search the information base for a specific problem-solving need across a variety of medical contexts. The ability to browse selectively and rapidly and the ability to integrate concepts from a variety of views are important potential advantages of a computer-based educational presentation.

A provocative use of information technology in medical education is the use of the computer as an expert system. In decision support applications, the computer provides interpretations of clinical data, selective access to the relevant medical knowledge base, and suggestions about the appropriate therapy. Most of the current computer-based expert systems have a very limited scope of coverage in terms of number of diseases included and use relatively primitive reasoning processes. However, this is an active area of investigation, and some of the recent developments appear to have considerable promise. The most promising applications at present are those that analyze a particular set of clinical manifestations and suggest specific diseases that might be the cause of the disease state and those that can selectively search the medical literature for relevant information.

A traditional application of information technology in medical education is in computer-based simulations. I argue that one can best learn to solve problems by problem solving. The skills required for problem solving in clinical medicine are difficult, if not impossible, to learn by passive activities such as lectures or reading. Currently our strategy of teaching clinical medicine is predominantly an apprenticeship experience; we ask the student to observe closely a good physician, to try to comprehend the meaning of and the justification for the teacher's actions, and then to do likewise. In contrast, computer-based simulations can provide a highly interactive structured environment with selective and comprehensive feedback. Such simulations can be used to allow the student to collect information in a selective fashion, to make interpretations, and to experiment with different decisions and different management strategies. The challenges provided by the simulations can closely mimic a variety of challenges encountered in actual medical practice and can provide the student with the opportunity to learn from mistakes in judgment or interpretation. Such "what-if" interactions are extraordinarily valuable learning experiences that cannot be provided in clinical education using actual patients. The development of these simulations requires a considerable amount of faculty time and programming resources. The educational and programming challenge is to create a computer program that can simulate an expert teacher able to respond to and critique all the possible choices a student might make in any given disease simulation. The program must be able to not only recognize optimal problem-solving behavior, but also respond to the student's requests for suggestions or an interpretation at any point in the interaction.

A related use of computer-based clinical simulation is in the assessment of an individual student's clinical competence. Currently, evaluation of a medical student's clinical skills is based primarily on an unstructured subjective judgment by the faculty and residents associated with the student's clinical rotation. This evaluation can be based more on personality characteristics than on a rigorous assessment of the student's clinical knowledge and problem-solving skills. As a result, it is possible for a student to graduate without ever achieving the desirable level of problem-solving skills. One of our objectives is to use computer-based simulations to assist in the identification of such students early enough in their clinical training to provide the necessary remedial education and supervision to develop such skills.

Perhaps the most powerful use of information technology as a remedy for some of the deficiencies in medical education would be the development of comprehensive computer-based medical record systems that were tightly integrated with easy access to educational resources. I argue that one of the most critical periods when medical education can occur is when the student is creating the medical record describing the clinical manifestations and listing the possible causes of the disease. On such an occasion, the student is most concerned with accessing relevant medical knowledge, and is thus most interested in using information technology to assist in the retrieval of useful factual information.

There are several challenges that must be met in the development and use of computer-based clinical record systems in medical education, including the technology to support the student's interaction with the computer, the structuring of the vocabulary used by the student in recording the clinical manifestations, the analysis of the user's query for specific medical knowledge, and the linking of the query to the appropriate section of the relevant knowledge base. At present such a computer application is very difficult because of the diversity of technology environments in most teaching hospitals, the lack of well-designed and comprehensive computer-based clinical record systems, the scarcity of computer-based knowledge bases, and the limited indexing functions of such knowledge bases. However, there is an awesome potential for systems that integrate education, knowledge acquisition, decision support, and protocol alerts with the work flow support adequate to create a medical record.

I have attempted to define some of the opportunities and limitations of the application of computer technology to medical education by using an analogy of the characteristics, the etiology, and the treatment of a disease state. Let us now consider some of the potential complications of the suggested treatments.

First, the typical environment where such developments are taking place is often fragile. It is not unusual that exciting applications in the different medical institutions are inordinately dependent on the enthusiasm and personal commitment of one or two key individuals and of a dean who has a vision of the importance of information technology. There is little overarching institutional commitment. If the key individuals lose interest, are discouraged by the lack of institutional support, or leave the institution, the computer applications are often abandoned. An important manifestation of the lack of institutional commitment on a national scale is that few medical schools consider development of innovative computer-based applications in medical education to be a legitimate

academic activity that should be given serious consideration when the faculty member is being considered for academic promotion and tenure. A major related issue is that few medical schools provide a departmental structure that is focused on improving the educational environment and supporting development and innovation in the use of technology in medical education.

The second complication is a lack of long-term financial support for the development of information technology applications in medical education. Most medical schools do not perceive that this is a high-priority need deserving of allocation of the limited funds available for educational innovation. Few foundations have an interest in support of the application of information technology, and such funds are usually available only for a limited research and/or evaluation effort. The only agency in the federal government that has a mandate to support the application of information technology to medical education is the NLM, and this support has been very limited in scope and duration. Part of the reason for the lack of financial support is related to the difficulty of carrying out a persuasive evaluation of the impact of computer technology in medical education. Those of us who try to institute changes in medical education are continually challenged to demonstrate that the new system is more effective than the previous system. There are two fundamental problems that make a rigorous evaluation difficult or impossible. The first is that it is enormously difficult to identify specific, explicitly defined objectives that are acceptable to the entire faculty. The second is that it is almost impossible to identify measurable outcomes that are relevant to the defined objectives. The irony of the challenge of evaluation of technologic innovation is that the present form of medical education has not been subjected to this type of evaluation.

Another major complication of the proposed treatments is the relative inability to achieve a tight integration of the information technology innovations into the classic curriculum. In many schools, the computer programs are elective, supplementary activities. It is rare for a computer-based teaching program to be recognized by the faculty and the curriculum committee as being a fundamental educational component that should be tightly coupled into a specific course involving all the faculty responsible for the course.

A commonly used "gold standard" of evaluation of any educational innovation is that the student will have improved short-term recall of the large set of facts presented in a limited section of the curriculum. The method of evaluation is that the student will have improved performance on a multiple-choice, knowledge recall test. Using such a standard for evaluation, I believe the attempt to demonstrate an advantage of computer technology is doomed. I am not optimistic that we will ever be able to demonstrate that the use of computer technology is better when measured against what should be the genuine objective of medical school: graduation of students who become competent, caring, and knowledgeable physicians who are committed to lifelong learning.

I am optimistic that information technology will become more widely used in medical education because I believe that medical students will find it so attractive that they will champion the use of computer-based teaching programs in all areas of the curriculum. Given the rapidly decreasing cost of computer hardware and the rapidly increasing experience of students with information technology, I believe an ever-increasing number of computer-based applications will be developed and implemented in medical curricula, even though there will be few serious efforts at systematic structured evaluation.

The last complication is the institutional fragmentation of medical schools in the United States. A common tendency is for each medical school to reinvent the wheel in terms of technologic innovation. This is not necessarily undesirable because part of the learning process of how to use the computer can best be achieved through program development. There is an increasing awareness of the existence of good medical education programs that are available from different medical publishers. However, I believe that all of us would benefit from a more consistent and comprehensive effort to identify our educational objectives and needs and through collaboration to share the costs and personnel effort in the development of medical educational programs. There will be problems of academic recognition, of royalties, and of lack of agreement in content that must be addressed, but I believe the field is mature enough to justify a broader effort to undertake such collaboration.

Continuing the analogy of considering medical education as a disease state, let us reflect on the potential outcomes of the proposed therapies. It is hazardous to predict the future of information technology in medical education, given the rapidity of changes that are occurring in the technology, in the software, and in the application of information technology in the practice of medicine. However, with some confidence I can predict that each year the underlying computer technology will be both more powerful and less expensive. The second prediction is that there will continue to be an increasing awareness on the part of medical faculties and medical students of the

high priority of the need to improve medical education, and of the potential contribution that can be made through the innovative use of information technology. I believe that the complications that I have identified will come to be of national and institutional interest and will be effectively managed. I am unequivocally persuaded that medicine will continue to need ready access to a vast amount of medical knowledge and will continue to be dependent on effective problem solving. Our challenges in medical education and in medical informatics will continue to evolve; the available technology will continue to become more powerful; and new ideas, new strategies, and new visions will continue to be voiced. Careers in medical informatics and its application to medical education will become increasingly exciting and rewarding. Most importantly, such a career will command the need for the highest degree of professional competency, vision, and imagination, combined with the age-old commitment to teach others the binding of wounds, the relief of pain, and the care of the sick. One could ask for nothing more.

Correction

In the editorial "Informatics: The Infrastructure for Quality Assessment and Quality Improvement in Nursing" that appeared in the May/June issue (JAMIA. 1995;2:198–9), the name of one of the conference participants was misspelled. On page 199, Helmer F. Martin should have been Heimar F. Marin.