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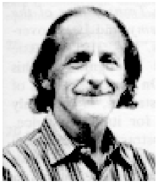

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Informatics and the Future of Biomedical Education Curricula

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Despite local fluctuations in financial support, the exponential growth of science and technology continues. At the present time we can observe at least an annual 4 percent growth in the number of papers that are written and indexed in the *Science Citation Index®* (*SCI®*) alone, and the growth of biomedical publications may be even larger. How is the medical practitioner and researcher to deal with this problem?

While it has been obvious for years that information science and technology is a bona fide academic discipline, medical educators do not yet recognize the need to help physicians to avoid information overload and effectively utilize medical knowledge. As Nina W. Matheson, director, Welch Medical Library, Johns Hopkins University, Baltimore, Maryland, and Donald A.B. Lindberg, director, National Library of Medicine, Bethesda, Maryland, note in the following reprint, "The time has come when medical schools must take action. Although rapid advances may bring yet unanticipated technologies, the need for educational adjustments is immediate."[1]

The term "informatics" was coined by A.I. Mikhailov many years ago. He is the director of both the Scientific Information Department, Moscow State University, and the All-Union Institute of Scientific and Technical Information (VINITI) in the USSR. He has also served on the editorial board of the *SCI*. In *Scientific Communications and Informatics*, Mikhailov and colleagues write that informatics is a "scientific discipline that studies the structure and general properties of scientific information and the laws of all processes of scientific communications."[2] (p. 365) The English term "information science" coincides with his definition of "informatics." Mikhailov notes that the "peculiarities in the development of the scientific information activity within individual countries and the specific characteristics of each language naturally affect the choice of particular terms."[2] (p. 371) (For more information on this book, see our review for *Nature*.)[3]

While the term informatics refers to all types of scientific information, Thomas L. Lincoln, professor of pathology, University of Southern California, Los Angeles, and Ralph A. Korpman, assistant professor of pathology, Loma Linda University, School of Medicine, California, have outlined a subspecialty of informatics called medical information science (MIS). They define MIS as "a distinct discipline that concentrates on the problems that arise when one attempts to integrate the rich knowledge base and behavioral variety of health care with the logical constraints of computer-oriented information processes."[4]

Medical information science is now recognized as a necessary discipline in many European medical school curricula. P.L. Reichertz, Department of Biometrics and Medical Informatics, Medical School Hannover, Federal Republic of Germany, notes that Germany and France have been successful in establishing MIS courses. Medical students can take MIS as an elective course, while physicians are offered MIS postgraduate training. In France, advanced MIS courses have been established for various branches of theoretical medicine, including biomathematics and informatics in various combinations.[5] J.H. van Bemmel, Department of Medical Informatics, Free University, Amsterdam, The Netherlands, and colleagues describe the success of a five-day course incorporating lessons in medical databases, hospital information systems, medical records, biologic signal analysis, and computer-assisted diagnoses.[6]

As yet, however, most US medical schools have not included medical information science in their curricula. In the report *Physicians for the Twenty-First Century*,[7] the panel on the General Professional Education of the Physician (GPEP) recommends shifting the educational emphasis in US medical education. Memorization of facts should be de-emphasized and the focus should be placed instead on the acquisition and development of skills, values, and attitudes that will prepare medical students to learn throughout their professional lives. The panel believes that independent, self-directed learning will develop, among other qualities, "the ability to identify, formulate, and solve problems; to grasp and use basic concepts and principles; and to gather and assess data rigorously and critically."[7] (p. 9)

To promote independent learning and problem solving in medical education, the panel believes that students should be required to seek, rather than be given, information. The panel recommends the development of information-science skills to promote the students' active search for information.[7] (p. 12) It would seem that the practical use of medical information science technology and the revision of medical education are two complementary goals.

However, Matheson and John A.D. Cooper, Association of American Medical Colleges, note that until recently information technology has not been used productively in the educational process. Faculty and student access to computing support has been limited and cumbersome, unless grant-supported. In addition, faculty members have yet to appreciate fully the opportunities that the new technologies offer in reducing the drudgery of information research and personal information file management.[8]

To address this problem, the GPEP panel recommends that "medical schools should designate an academic unit for institutional leadership in the application of information sciences and computer technology to the general professional education of physicians and promote their effective use."[7] (p. 14) Unfortunately, the economic issues involved here are quite critical. While faculty members can use their grant funds to absorb the cost of information technology, students usually have no access to such funding. We intend to cover this topic in the future.

The failure of educational institutions to rise to the challenge of the information revolution has placed an enormous burden on the "marketing" departments of database producers. From the first days of the *SCI*, ISI® recognized the need for teaching information research skills to scientists. This is often done in cooperation with librarians who are usually overburdened with teaching and administrative duties. Our programs concentrate on improved information-retrieval skills. We have provided an educational lecturer program since 1975 that develops user searching skills.[9] Most recently, ISI has launched an expanded online-training program in the form of "hands-on" workshops that review the commands of specific database vendors and teach users to search the ISI files on those vendors' databases. And, in conjunction with a new, more comprehensive edition of *Sci-Mate*®, we have introduced a range of services to deal with microcomputer-related problems.[10] For instance, *Sci-Mate* is useful for scientists who wish to access a variety of database vendors such as Bibliographic Retrieval Services (BRS), DIALOG, National Library of Medicine (NLM), German Institute for Medical Documentation and Information (DIMDI), DATASTAR, and so on. *Sci-Mate*, PaperChase, and other systems can help in training users to access a variety of databases.

Regardless of our commitment to improve information-science skills, I believe that the burden for teaching these skills should primarily reside in educational institutions. Medical information science or medical informatics has become as essential to the medical curriculum as any laboratory science.

In the article that follows, Matheson and Lindberg explore impediments to the incorporation of medical information skills into medical education and recommend fundamental changes that need to be made to our medical education system.

We thank the authors and the *Journal of Medical Education* for permission to reprint this excellent article in *Current Contents*®.

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My thanks to Lisa Holland for her help in the preparation of this essay.

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Subgroup Report on Medical Information Science Skills*

Nina Matheson and Donald A. B. Lindberg, M.D.

Medical information science is the emerging academic discipline through which the skills of information management may be learned (1, 2). It is the science of "using system analytic tools ... to develop procedures (algorithms) for [the] management, process control, decision making, and scientific analysis of medical knowledge." (3) Its roots are in computer and information science on the one side and in experimental medicine on the other. The principles and theories of information management and decision making—derived through its research, investigations, and development of tools—are applied to medical research, clinical practice, and education. Ultimately, the application of medical information science to learning should result in new approaches to medical education.

*Prior to the submission of this report to the Project Panel in June 1983, the report received critical review in February 1983 by Marsden S. Blois, M.D., Ph.D., director of medical information sciences, University of California, San Francisco, School of Medicine; Gerald Oppenheimer, director, University of Washington Health Sciences Library; and Edward Shortliffe, M.D., Ph.D., assistant professor of medicine and computer science, Stanford University School of Medicine. The authors express appreciation for their helpful insights.

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Significance

Information-handling technologies and telecommunications are basic tools of modern society. Efficient and effective business, legal, financial, and governmental operations must have online access to records, files, and relevant data bases (4, 5). The need to provide opportunities to all students to acquire knowledge about and skills in information management is increasingly recognized by the higher education community (6-8). The need for an equivalent response in medical education grows more apparent as well (9-16).

As yet American medical education has done little to prepare physicians to be effective in such a world. Medical computer science is not recognized as a relevant field of study in American academic medicine as it is in West Germany, the Netherlands, France, Scandinavia, and Japan, where curricula include courses in medical informatics (17). Only a handful of American medical schools have the personnel and computer resources to provide education in the principles and operation of medical information systems. Despite continuing pressures on the student and the practitioner due to information overload (18), there has been little concerted action to bring about an electronic knowledge base in support of education, health care, or research. Efforts to date have been fragmented and ad hoc, and concentrated in areas of administration and financial systems (19, 20). Neither current methods of medical teaching nor the storage of clinical information [is] consistent with the shift taking place in the world at large.

New online data bases providing chemical information, bibliographic information, and social and economic information are appearing daily (21, 22). Electronic textbooks, clinical decision support systems such as CADUCEUS and MYCIN, and knowledge bases foreshadow an entirely different environment (23, 24). Sophisticated computing systems will encode and make available increasing amounts of medical and scientific knowledge, beliefs, and inferences. The skills associated with information management are essential to facilitate the acquisition by medical students of (*a*) fundamental knowledge, (*b*) basic learning techniques, (*c*) clinical skills, and (*d*) methods for critical appraisal and the effective use of research literature.

Proposed Approaches

The time has come when medical schools must take action. Although rapid advances may bring yet unanticipated technologies, the need for educational adjustments is immediate. At a minimum, medical schools should provide opportunities to students for acquiring technical skills that will help establish the scientific foundations for basic research and clinical applications of biomedical computation. These skills can only be developed optimally in a medical setting.

Levels of understanding of the principles of information handling can be described by a simple taxonomy of skills as shown in Exhibit 1. In general, baccalaureate students need general computer competence through Level 3. All medical students need computing skills in the medical context through Level 4 and some will aspire to and achieve Level 5; residents and fellows should function at Levels 4 and 5. Levels 6 and 7 describe skills for those working as research scientists in the field of medical computer science.

EXHIBIT 1
Taxonomy of Skills

Level 1—Using basic information-handling tools
Level 2—Independent learning about computers and information management
Level 3—Using computer systems and accessing databases
Level 4—Knowledgeably using systems and specialized databases
Level 5—Perceiving new applications
Level 6—Building systems for personal application
Level 7—Tool building

BACCALAUREATE LEVELS

Following are some of the competencies that might be expected of baccalaureate students at Level 1 through Level 3:

Level 1—Baccalaureate students at Level 1 are able to use basic information-handling tools. They acquire a general level of computing knowledge needed for competency in daily life and to get through the undergraduate years. Skills at Level 1 include use of devices for course work document development, for electronic mail, for consulting library systems, for searching public data bases, and for using online statistical routines for analysis of data.

Level 2—Baccalaureate students at Level 2 learn independently about computers and information management. They have sufficient knowledge and skills to locate information, evaluate it, and apply it to learning and professional tasks.

Level 3—Baccalaureate students at Level 3 understand computers and information management tools well enough to develop information and education support systems for their personal use. They are knowledgeable consumers and [are] able to assess the value of new emerging technologies in an informed manner.

Medical School Levels

The medical students should possess the undergraduate level skills and be able to apply them in medical contexts. In the medical environment, Level 1 through Level 4 competencies include some of the following:

Level 1—Medical students at Level 1 are able to apply their undergraduate medical skills in the following medical contexts:

1. They understand the uses, purposes, and limitations of computers in carrying out physician tasks including (*a*) clinical records (patient management files); (*b*) clinical investigations (interpretation of test reports and diagnostic images); (*c*) clinical decision making; (*d*) monitoring therapeutic regimens; and (*e*) recall of literature, interpreting its relevance, and applying new knowledge.
2. They understand the uses, purposes, and limitations of computers in carrying out educational tasks including (*a*) learning support (biostatistical analysis and computer-based education); (*b*) information handling (information storage and retrieval systems for lifelong use, retrieval of literature from online bibliographic systems, assessment and evaluation of scientific and clinical literature, and writing skills); and (*c*) self-assessment (use of test banks).

Level 2—Medical students at Level 2 have sufficient knowledge and skills from Level 1 introductions to pursue independent learning about information tools in medicine according to their abilities and interests.

Level 3—Medical students at Level 3 are able to use devices on a selective basis to access systems and to employ them to suit individual requirements for knowledge and skill development. These skills include the ability to (*a*) access physician task support systems, (*b*) use online bibliographic search services, and (*c*) generate new files for personal research and learning.

Level 4—Medical students at Level 4 have sufficient experiences to (*a*) use current models of formal medical decision making; (*b*) understand the practical institutional and personal problems in the automation of clinical patient records, medical data bases, and other clinical computing systems; and (*c*) critique, select, and use systems for medical office, personal business, and time management. Levels 5, 6, and 7 are graduate-level proficiencies that are likely to develop only in the especially interested or gifted individuals.

These levels of skills and knowledge can be acquired through traditional lectures, demonstrations, hands-on laboratory experiences, research experiences, small group discussions, case studies, and computer simulations. Personal interaction with information systems is essential to learning, and teaching will be most effective when it is based on local medical examples. Schools that cannot offer these opportunities for learning should foster extramural electives and provide network connections to provide experiences with special applications (25). Some schools may collaborate in the creation of computational systems and materials on a shared basis, both to offer educational opportunities and to provide tools for use in preclinical and clinical course work.

Impediments to Progress

The major impediments to success in providing opportunities for medical students to acquire skills in medical information sciences are the following:

1. The failure of institutions to acknowledge the importance of medical information sciences and to provide students with opportunities to gain skills results in (*a*) a lack of local support for personal computing, and (*b*) a lack of access to a variety of available medical information systems.
2. The failure to assign departmental responsibility and authority for the educational program in medical information sciences, a field whose teachers are drawn from many disciplines—medicine, engineering, computer sciences, library sciences, operations research, and behavioral sciences—results in (*a*) a lack of experienced role models in the institution able to demonstrate the mainstream relevance of the field to medical practice, (*b*) a lack of resources to provide demonstrations and hands-on laboratory experiences for students, and (*c*) a lack of educational experiences in the uses of literature retrieval services and techniques and awareness of their application to continued learning.

Research

Medical information sciences is a youthful and active research field with many important and fundamental discoveries to be made:

1. The structure of information storage and retrieval remains poorly understood; and the identification of the nature and character of medical knowledge, its representation, and its organization need exploration and experimentation.

2. Existing clinical consultation systems, such as CADUCEUS and MYCIN, are in early and experimental stages of development, in part because of the lack in medicine of a theoretical basis and systems analysis of the components of medical knowledge, fundamental clinical skills, and medical education. This is another important research area.

Recommendations

1. *Medical schools should establish academic units for medical information science with faculty positions and an acknowledged place in the four-year curriculum. Through such means medical faculties can explore creative uses of information management technologies in teaching, learning, research, and clinical care.*

2. *Medical schools should create an environment in which the student is able to develop proficiency in the use of the computer as a tool in medical research, education, and clinical practice. In particular, the student should be able to use and build learning support systems for graduate and postgraduate education.*

3. *The ability to use basic information-handling tools and personal computing skills and the ability to learn independently in this field should become prerequisites for admission to medical school.*

4. *Universities, medical schools, and federal agencies should provide increased recognition of and support for the basic research issues that remain to be addressed and resolved by medical computer scientists.*

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