Careers in Medical Informatics ■

Medical Informatics Education:

The University of Utah Experience

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A b s t r a c t   The University of Utah has been educating health professionals in medical informatics since 1964. Over the 35 years since the program's inception, 272 graduate students have studied in the department. Most students have been male (80 percent) and have come from the United States (75 percent). Students entering the program have had diverse educational backgrounds, most commonly in medicine, engineering, computer science, or biology (59 percent of all informatics students). A total of 209 graduate degrees have been awarded, with an overall graduation rate of 87 percent since the program's start. Alumni are located in the United States (91 percent) and abroad (9 percent); half (51 percent) have remained in Utah. Former students are employed in a wide variety of jobs, primarily concerned with the application of medical informatics in sizable health care delivery organizations. Trends toward increasing managerial responsibility for medical informatics graduates and the emergence of the chief information officer role are noted.

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As medical informatics has become a distinct discipline,[1] training programs leading to graduate degrees in medical informatics have emerged. The University of Utah was among the first institutions in the United States to offer graduate education in medical informatics and has been granting related degrees for more than 30 years. Since the program's inception, a sizable number of students have been educated and have assumed a variety of informatics positions, predominantly inside but also outside the health care industry. This article describes the students who have pursued a medical informatics education at the University of Utah and the subsequent employment of these students.

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Overview of the Program

The Department of Medical Informatics at the University of Utah evolved over time. The first graduate students formally studying computer applications to medicine at the University of Utah began work in 1964 under the leadership of Dr. Homer R. Warner and his associates in the Department of Biophysics and Bioengineering in the School of Engineering. In 1972, the department was split into the Department of Bioengineering in the School of Engineering and the Department of Medical Biophysics and Computing in the School of Medicine, the latter being directed by Dr. Warner. In 1985, the Department of Medical Biophysics and Computing was formally renamed the Department of Medical Informatics. Doctor of Philosophy degrees awarded by these departments were initially in medical biophysics and computing and more recently in medical informatics. A Master of Science in Medical Informatics degree has been awarded since 1976.

The department is internationally recognized for its contributions to computer applications in clinical care, medical education, and research. The mission of the department is to improve health care outcomes

through information systems in both the private and public sectors of the health care industry. To accomplish this mission, the department assumes three major responsibilities:

- To educate medical professionals, medical informaticists, and the health care community about the field of medical informatics;

- To promote and conduct research to broaden medical informatics knowledge; and

- To serve health informatics professionals and consumers by participating in relevant professional societies, editorial boards, and continuing education programs, while maintaining medical informatics leadership in the community.[2]

To execute its mission, the department's current education and research opportunities range from basic to applied sciences, and since 1995 encompass five tracks leading to the MS and PhD degrees. These department tracks are health information systems, expert systems, genetic epidemiology, health care quality, and medical imaging. Historically, genetic epidemiology emerged as a computer-intensive specialty at the University of Utah and has organizationally remained a part of the Department of Medical Informatics, despite its tangential connection to the other four tracks. In the early years of the department, much of the research focused on computer applications in physiology as applied to clinical applications in the cardiovascular laboratory or intensive care units.

The program's curriculum has been previously described.[3] Since this earlier publication, the University of Utah has changed from a quarter to semester system and its course offerings have been extensively revised. The original survey of computers in medicine course has been expanded into a core course in medical informatics. In response to changes in the application of information technology to health care, several new courses have been added to the original offerings, including medical informatics vocabulary and standards, networks and communication, clinical database design, application programming, primary care health information systems, health care quality improvement, Web site development, applied statistics, and research ethics. Current course offerings are detailed in Table 1. A wide range of additional elective courses are available in other departments. Despite these changes, the Department of Medical Informatics has retained its focus of providing comprehensive medical informatics education, requiring a research project that culminates in either a thesis leading to an MS degree or a dissertation leading to a PhD degree.

The department has 14 full-time faculty and 14 adjunct faculty. A wide variety of sites are available for the department's teaching and research operations, including the School of Medicine at the University of Utah, University Hospital and the University of Utah Health Network, University Research Park, the Salt Lake Veterans Administration Medical Center and the VA's Information Resources Management Field Office (IRMFO), and several facilities of Intermountain Health Care, most importantly LDS Hospital and Primary Children's Medical Center. Several medical informatics students have also completed research projects at private firms involved in health care computing in the Salt Lake City area.

The pivotal role of LDS Hospital in the development of the medical informatics program merits particular emphasis. LDS Hospital was the experimental lab that gave birth to the HELP (Health Evaluation through Logical Processing) system, one of the earliest and still one of the most thoroughly integrated clinical information systems in routine use for patient care.[4-6] Multiple applications of the HELP system have proved their utility in clinical practice.[7-11] Much of the current emphasis on the development and implementation of health information systems originated from the accomplishments of the faculty and students of the Department of Medical Informatics at LDS Hospital.

Methods

The files and databases of the Department of Medical Informatics at the University of Utah in Salt Lake City, Utah, were reviewed to compile a comprehensive listing of all graduate students in the department from

Table 1 ■

Medical Informatics Course Offerings at the University of Utah

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Medical informatics core course	Application programming
Medicine for engineers and scientists	Primary care health information systems
Health information systems	Web site development
Medical decision making and knowledge engineering	Mathematical modeling of biological systems
Health care quality improvement	Applied statistics
Genetic epidemiology	Research design
Vocabulary and standards	Research ethics
Networks and communication	Journal club
Clinical database design	Graduate seminar
MS thesis research	PhD dissertation research
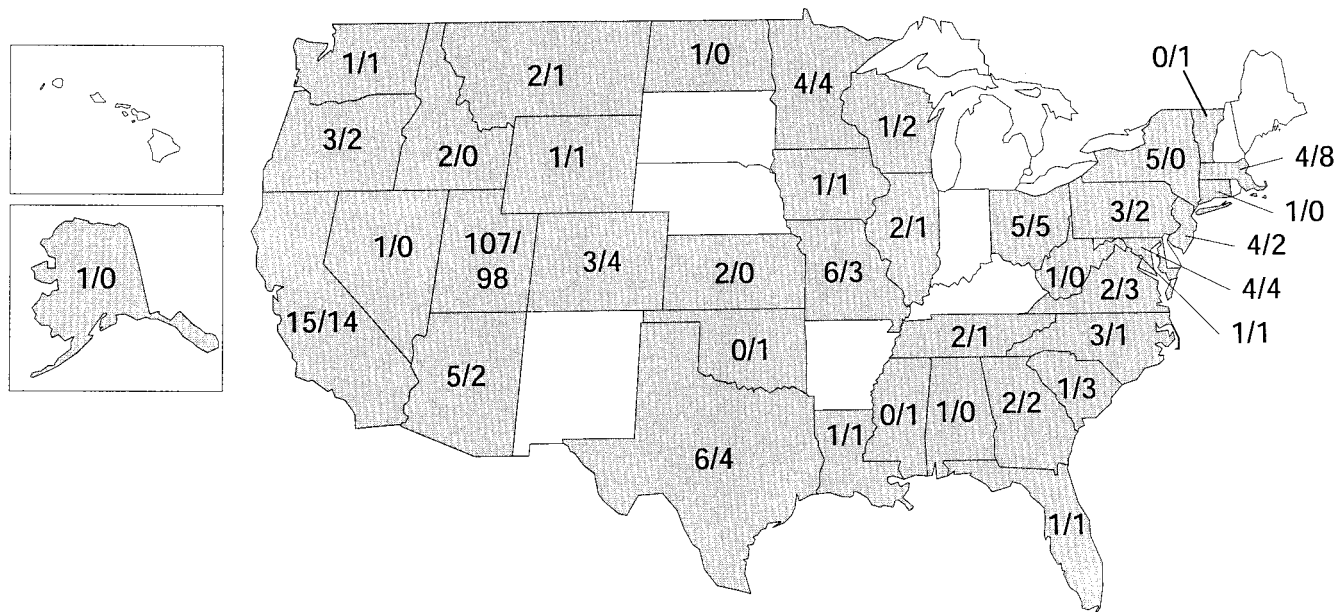
F i g u r e 1 States of origin and current locations of the 75 percent of medical informatics students at the University of Utah who have come from the United States. The first number shown for each state indicates the number of students who came from there; the second indicates the number of graduates currently located there. No students have come from the 12 unshaded states, and those states have not been a destination for graduates.

1964 to the present.* An attempt was made to locate all alumni of the Department of Medical Informatics —by telephone, e-mail, letter, or in person—to verify the current employment status of former students. Approximately 30 "fellows" in the Department of Medical Informatics, who were not pursuing an informatics degree (e.g., health care professionals on sabbatical, medical students, and international visitors), were excluded from the analysis. In 1990, the University of Utah created a separate Nursing and Health Informatics Program in the College of Nursing[12,13]; this program is not included in the present report.

Results

Demographics

A total of 272 current and former graduate students were identified. The ages of students on admission to the program ranged from 21 to 55 years, with a mean age of 30.3 years. The majority of students were men,

with 218 male (80 percent) versus 54 female students (20 percent). The student body has included three married couples of whom both husband and wife were medical informatics students. The geographic origin of students from the United States is shown in Figure 1. The majority of students have come from Utah, although 36 states have been represented in the student body. Two hundred five students (75 percent) originated in the United States, and 67 students (25 percent) were from other countries.

Pre-informatics Education

The educational background of students has been diverse. Details of the previous education of medical informatics students were available for 249 of 272 students (92 percent) and are given in Table 2. Of these 249 students, all held an undergraduate degree, in keeping with the graduate level of the program. Multiple prior degrees were remarkably common: 96 students (39 percent of the student body) had earned not only an undergraduate degree but also one to three graduate degrees prior to beginning the medical informatics program.

Fifty-seven physicians entered the program after earning their medical degrees. Two additional physicians received concurrent degrees from the University of Utah, one earning an MD and an MS degree in medical informatics and another earning an MD and a PhD degree in medical informatics. Physicians in the student body have represented both general practice and a broad range of 19 medical specialties, detailed

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*For the purposes of this paper, the following definitions have been used: *graduates*, medical informatics students who have completed their course of study and received a graduate degree (MS or PhD); *nongraduates*, medical informatics students who have completed their course of study but have not yet received a graduate degree; *alumni*, medical informatics students (both graduates and nongraduates) who have completed their course of study; and *current students*, medical informatics students still actively pursuing coursework or research directed toward a graduate degree.

Table 2 ■

Previous Education of Medical Informatics Students (*N* = 249)*

Discipline	No. of Students (%)
Medicine	59 (20)
Engineering	48 (16)
Computer science	35 (12)
Biology	32 (11)
Mathematics	27 (9)
Chemistry	20 (7)
Physics	19 (6)
Nursing	9 (3)
Medical technology	9 (3)
Other medically related fields	18 (6)
Other nonmedical fields	25 (8)
TOTAL†	301 (101)

*Of the 272 students who have studied in the Department of Medical Informatics, 23 were excluded because their previous education was not known.

†The total number of students exceeds 249 because of multiple degrees and majors. Percentage totals exceed 100 percent because of rounding.

in Table 3. Forty-four of 57 physicians (77 percent) entering the program were specialty trained. Six physicians were double boarded.

Informatics Education

The program has 53 current students at various stages of study toward medical informatics graduate degrees. Former students total 220, of whom 191 (87 percent) received their graduate degrees and 29 (13 percent) left the program without completing the requirements for their degrees. One student who has completed his MS degree and is currently pursuing a PhD in the department has been counted as both a graduate and a current student in these figures. One hundred twenty-one MS degrees and 88 PhD degrees have been conferred (58 and 42 percent of degrees, respectively). Of the 38 physician alumni who earned an MS or PhD degree in medical informatics, 24 earned MS degrees and 14 earned PhD degrees. A total of 209 theses and dissertations (121 master's theses and 88 doctoral dissertations) have been completed since the program began. Eighteen students completed both a master's thesis and a doctoral dissertation. The University of Utah allows candidates to pursue the PhD degree without requiring a prior MS degree, and most doctoral students have chosen such a route. The breakdown of thesis topics by type is shown in Table 4.

The amount of time that graduating students spent in the department ranged from 1 to 11 years, with a

Table 3 ■

Specialties of Physician Medical Informatics Students and Number of Physicians Who Specialized Before Entering or After Completing Informatics Program

Medical Specialty	No. Specializing Before	No. Specializing After
General practice or no specialty identified	23	0
Internal medicine	11	2
Pediatrics	6	0
General surgery	5	0
Anesthesiology	3	1
Family practice	2	2
Pathology	2	1
Emergency medicine, neonatology, or obstetrics/gynecology	2 each	0
Cardiology	1	2
Diagnostic radiology	1	1
Radiation oncology	1	1
Dermatology, gastroenterology, infectious disease, neurology, pediatric cardiology, perinatology	1 each	0
Psychiatry	0	1
TOTALS*	67	11

*The totals exceed the number of physicians in the program because of double boarding.

mean of 4.0 years. Master's students completed their degrees in 3.1 years, on average, while doctoral students averaged 4.5 years. The department now requires that master's degrees be completed in three years and doctoral degrees in seven, although occasional exceptions may be made in special circumstances.

The graduation rate during the program's initial two decades was impressive: All 78 students admitted from 1964 to 1982 successfully completed their graduate degrees. The first student to fail to graduate en-

Table 4 ■

Types of Medical Informatics Theses

Thesis Type	No. of Theses (%)*
Physiology	75 (37)
Expert systems	54 (26)
Health information systems	46 (22)
Medical imaging	16 (8)
Genetics	12 (6)
Health care quality	2 (1)
TOTAL	205 (100)

*Four unavailable and unclassified theses were excluded.

Categorization of Employment of Medical Informatics Alumni

Category	Description	Representative Job Titles
Operational informatics	Positions applying medical informatics in health care delivery organizations or related firms	Medical informaticist, programmer, analyst, Webmaster, consultant, software engineer, systems engineer, project manager, technical sales, applications development, biomedical engineer, data manager, chief information officer, information specialist, technical specialist, project lead, computer professional, director, medical administrator, medical director of information services, support supervisor, information systems manager, product analyst, clinical systems designer, systems and service manager, clinical decision support project manager
Academia	Positions teaching medical informatics, computer science, or medicine at educational institutions	Department chairman, associate dean, professor, associate professor, assistant professor, clinical instructor, director of imaging technology, program director, statistician
Management	Positions concerned with organizational management and leadership	Chairman, chief executive officer, president, vice president, assistant vice president, chief information officer, chief medical officer, director of computer science, medical administrator, medical director of information services, team leader, corporate manager, general manager
Medical practice	Positions focusing on clinical practice and direct patient care	Variable, often dependent on academic appointment
Research	Positions focusing on applied research	Director of research and development (R&D), vice president of R&D, director of research, research associate, research professor, research scientist, R&D manager
Nonmedical information technology	Positions applying information technology outside the health care delivery domain	Database administrator, technical staff, director of managed data services, information technology planning

tered the program in 1983. The graduation rate for students admitted from 1983 to 1988 was 91 percent (67 of 74).

Post-informatics Education

Although the students entering the program typically had a high level of educational accomplishment, medical informatics graduate study was for many not their final educational experience. Nineteen students pursued additional study after completing the medical informatics program at the University of Utah. Nine students went on to medical school or subsequent residency training, and two others who completed concurrent MD/MS or MD/PhD degrees undertook specialty training; these physicians are counted in Table 3.

Employment of Medical Informatics Alumni

Former students of the program have pursued a variety of employment opportunities, and more than half (29 of 53, or 55 percent) of current students are employed part or full-time. Many alumni and working students (85 of 222 in the work force, or 38 percent) discharge several responsibilities concurrently and defy classification in a single job category. As a result, a wide variety of job titles have emerged; representative job titles are categorized in Table 5. The employment status and types of jobs undertaken by the program's alumni and working students are detailed in Tables 6 and 7.

The program's alumni work in a wide variety of organizations, which may be grouped into the narrow

Table 6 ■

Current Employment Status of Medical Informatics Alumni and Students

Employment Status	No. of Alumni and Students
Employed:	
Alumni	193
Current students	29
Not employed:	
Alumni	2
Current students	24
Retired	1
Deceased	2
Unknown	21
TOTAL	272

Table 7 ■

Types of Jobs Held by Employed Alumni and Students

Job	No. (%) of Alumni and Students*
Operational informatics	148 (67)
Academia	41 (18)
Medical practice	35 (16)
Management	31 (14)
Research	26 (12)
Nonmedical information technology	14 (6)
Other	7 (3)

*Totals exceed 222 students and alumni and 100 percent because many alumni and students hold positions with multiple concurrent responsibilities.

range of categories shown in Table 8. Of the 53 alumni working for integrated delivery systems, 32 work for Intermountain Health Care, the dominant regional integrated delivery system, which is based in Salt Lake City and is a strong supporter of the medical informatics program at the University of Utah. Intermountain Health Care is the parent corporation of LDS Hospital, where much of the department's seminal work has been performed. Another 26 alumni work for the University of Utah.

Former students are widely distributed across the United States, as shown in Figure 1. The 18 alumni (9 percent) who are not in the United States live in a number of other countries, including Austria, Bahrain, Brazil, Canada, France, Germany, Japan, Korea, the Netherlands, Poland, Taiwan, the United Kingdom, and Uruguay.

Evolution of the Program

The University of Utah medical informatics program has evolved significantly over the 35 years since its inception. Student interest has increased considerably in recent years, with approximately 50 applications for admission to the program now being received annually. The trend has been to larger entering classes, averaging 15 students per year over the last four years (Figure 2). In the early years of the program, only male students applied for and pursued medical informatics study; the first female student was admitted in 1974. Women made up 20 percent of students over the entire 35 years of the program's existence and 23 percent of the last four entering classes. The majority of medical informatics students were Utah residents in the early years of the program, representing 54 of 92, or 59 percent of students during the program's first 20 years. Only three international students entered the

Table 8 ■

Distribution of Medical Informatics Alumni by Type of Organization

| Organization Type	Number of Alumni (%)
Industry	72 (37)
Integrated delivery system	53 (27)
Educational institution	44 (23)
Medical practice	11 (6)
Government	6 (3)
Hospital	4 (2)
Military	3 (2)
TOTAL*	193 (100)

*The total is less than the sum of former students, because the current organization for 15 alumni is not known.

program during this period, as compared with 89 U.S. students. A geographically more diverse student body has emerged in subsequent years, with more students from other states in the United States as well as from a number of other countries. International student representation peaked at about 50 percent of classes entering from 1986 to 1991 but has averaged 23 percent for the four most recent entering classes. Physicians have, overall, represented 20 percent of medical informatics students. The 53 current students include 21 physicians (40 percent), of whom 16 are pursuing MS degrees and five are PhD degree candidates.

Discussion

Two previous reports briefly reviewed the structure of the University of Utah medical informatics program and the employment of its graduates.[1,3] Although much has appeared in the medical literature about both undergraduate and graduate medical informatics education, little has been written about the outcomes

F i g u r e 2 Sizes of the medical informatics classes at the University of Utah.
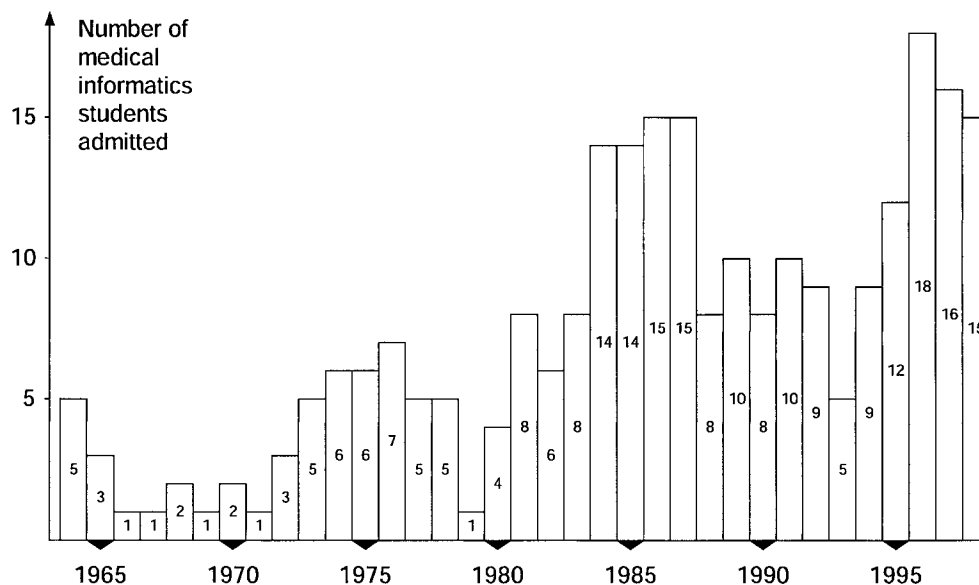
for those who pursue such specialized training. In Europe, the University of Heidelberg has been the exception, reporting questionnaire responses to a survey of graduates from their program.[14] The University of Victoria has reported its 10-year experience as the only institution in Canada offering a BS degree in health information science.[15] Information about the employment of the Victoria program's 113 graduates from its first decade was detailed; having just admitted its first graduate students, no results for those with the additional education are yet available. No detailed reports addressing the fate of medical informatics graduates in the United States have been published.

The present report characterizes those who have undertaken medical informatics education at the University of Utah over the past 35 years and offers specific insights into the employment of those so trained. The program is well able to provide a retrospective review of its experience over a prolonged period under remarkably stable leadership; only two chairmen have led the department over its 35 years. The program's founder, Dr. Homer R. Warner, provided direction and vision between 1964 and 1996, and much of the department's success is directly attributable to his accomplishments. The department has produced the largest group of medical informatics professionals educated at any institution in the United States. The overwhelming majority of former students (188 of 193, or 97 percent) are still in the work force, a situation which will begin to change increasingly as the program's alumni from the 1960s approach retirement.

The 4:1 ratio of male to female medical informatics students is consistent with the previously reported disparities between men and women in the computer science field. Although women constitute slightly more than half of the U.S. population and 45 percent of employed workers, they represent only 30 percent of employed computer scientists and 10 percent of those at the doctoral level.[16] While the department has in recent years seen an increase in interest in medical informatics education among women, men still remain decidedly in the majority.

Multiple job roles are common among alumni of the program. The largest proportion of the program's former students (67 percent) is involved in positions we have characterized as "operational informatics." More than half the physician medical informatics students (33 of 58, or 57 percent) have continued in medical practice following their informatics training. Five percent of informatics alumni have left the health care domain altogether for information technology positions in other sectors. Most alumni are employed by a variety of health care organizations, covering the spectrum from medical practices to hospitals to integrated delivery systems in both the public and private sectors.

Although the majority of medical informatics alumni work for health care organizations, a few entrepreneurs have emerged from our students and faculty to create their own companies. These new firms include two startup firms, which eventually merged into the health information systems division of a major nationwide industrial firm to form one of the industry's major developers of expert systems, patient care sys-

tems, and new methodologies for classifying medical information. Other firms specializing in medical decision support software, medical imaging services, and health care products have also been started by the department's alumni. In addition, a leading genomics company discovering important disease genes and their biological pathways has its roots in the University of Utah's medical informatics department.

As a consequence of rapidly changing technology, increasing regulation and paperwork, and increasing competitive pressures (at least in part resulting from the emergence of managed care), a notable trend in the medical informatics field has been the appearance of the position of chief information officer (CIO).[17] Two Utah graduates carry the *specific* CIO job title, and 19 others are in senior information management positions at an equivalent level of responsibility, representing, in total, 9.7 percent of Utah alumni. A similar role is evolving for the position of chief medical information officer (CMIO), typically a practicing physician charged with responsibility for bridging the gap between the clinical medicine and information science domains in a health care delivery organization.[18] It has been noted that organizations unable to muster sufficient clinical informatics leadership will find themselves at a competitive disadvantage directly because of their inability to implement advanced information systems.[19] Performing at the CIO/CMIO management level requires a combination of technical knowledge, leadership, communication, and business skills.[20] A medical informatics curriculum should provide the educational foundation to prepare motivated graduates to perform successfully in the CIO and CMIO roles. Some educational institutions have oriented their programs toward training such professionals.[21] The Department of Medical Informatics at the University of Utah is modifying its curriculum to allow students to pursue management and planning courses in the university's Master of Business Administration (MBA) program in addition to the traditional informatics curricula that include health information systems, expert systems, genetic epidemiology, health care quality, and medical imaging.

The University of Utah medical informatics program has shown a consistent commitment to training qualified professionals in the emerging discipline of medical informatics. Given the pace of change pervading both health care delivery and information technology, no such program could or should remain stagnant. Continuous refinement and modification in response to change will remain an important theme for informatics education in the future. Any such educational program must be designed with an eye on the marketplace's demand for and use of informaticians, hence the importance of following the professional destinies of those so trained.

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