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## WORKSHOP: COGNITIVE AND SOCIAL SCIENCES FOUNDATIONS FOR MEDICAL EDUCATION AND TRAINING IN THE INFORMATION AGE

### Medical informatics and medical education in Canada in the 21st century

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#### Abstract

The advances of health informatics over the last 50 years are briefly sketched to reveal the pervasiveness of their applications in health and health care. The relations to research in health informatics and health are pointed out. From this perspective it is argued that the evolution of consumer health informatics in the last decade has had a profound impact on the practice of medicine, on patient-physician relations and, hence, on the requirements for medical education. The different access to information and how it is used in educational environments will also dramatically affect how curricula are structured both at undergraduate and postgraduate levels. The impact of health informatics on medical education is further elaborated, and the requirements on infrastructure in support of this education are detailed. This infrastructure goes beyond instructional laboratories and includes academic units for medical informatics and, most importantly perhaps, funding resources and adjudication capacity for health informatics research and their integration into the Canadian research organization and the new Canadian Institutes of Health Research.

#### Résumé

Les progrès en informatique de la santé depuis 50 ans sont brièvement esquissés pour montrer à quel point leurs applications se sont répandues dans le domaine de la santé et des soins de santé. Les relations avec la recherche en informatique de la santé et en santé sont mentionnées. C'est ainsi que l'évolution des applications pratiques de l'informatique de la santé au cours de la dernière décennie aurait eu, dit-on, des répercussions profondes sur la pratique de la médecine, sur les relations patient-médecin et, par conséquent, sur les exigences en matière d'éducation médicale. L'accès différent à l'information et la façon dont elle est utilisée dans les milieux de l'enseignement auront aussi de très fortes répercussions sur la façon dont les programmes d'études sont structurés tant au premier cycle qu'au deuxième. Les répercussions de l'informatique de la santé sur l'éducation médicale sont approfondies et les exigences relatives à l'infrastructure servant à faciliter cette éducation sont précisées. Cette infrastructure va au-delà des laboratoires d'enseignement et elle comprend les services universitaires en informatique médicale et, plus importantes peut-être, les ressources financières et la capacité d'évaluer la recherche en informatique de la santé et d'intégrer ces facteurs dans l'organisation de la recherche au Canada et dans les nouveaux instituts de recherche en santé au Canada.

## Introduction

Medical or health informatics has been defined as “the field that concerns itself with the cognitive, information processing, and communication tasks of medical practice, education, and research, including the information science and the technology to support these tasks.”<sup>1</sup> The discipline uses models and does experiments and makes observations as in the biologic sciences. It operates, however, inside the complexity of a human organization, with less recourse to in vitro experiments and focus on 1 variable at a time, but uses methodologies and strategies to achieve advances that interact with the complexity of the contexts where these advances are developed and applied. It has been characterized as a “design discipline,”<sup>2</sup> similar to architecture, concerned with the design and implementation of artifacts that enable the promotion and delivery of a defined purpose, in our case health and health care. Health informatics is also a practical science<sup>3</sup> in that it aims to achieve changes in the state of reality, as much as developing insights into the structure and function of reality, as is the case in theoretical sciences.<sup>4</sup> In pursuit of effecting desirable changes to health and health care, health informatics integrates the insights of a variety of theoretical sciences, including mathematics, computer science and engineering, information science, and the cognitive, social and health sciences. On this basis, it develops sociotechnical systems for the acquisition, storage, communication and evaluation of health data in support of information processes in health. This new field emerged during the middle of the 20th century and matured to the extent that it is now an integral part of health and health care. This fact, we argue, must be reflected in medical education, particularly in Canada, which is a country of vast geographic distances, pronounced inequalities in the distribution of its population density, and of the associated availability of medical and other high technology services. The cultural diversity of Canadians is a further reason for a specific Canadian brand of health informatics infrastructure that bridges ethnic and other cultural diversities of Canadian society. In this presentation, we provide an overview of the role of health informatics in health and health care, and derive conclusions for a health informatics infrastructure in medical education.

## The role of health informatics in health and health care

Much of the development in health informatics over the past 5 decades has centred on the support of planning and delivery functions of health care. This is the realm of management information systems, hospital information systems, and so on. In pursuit of this, health informatics has drawn upon, as well as enriched, health research, and on the way has generated the field of health informatics research. With the advent of ubiquitous powerful computing capacity and Internet-based connectivity in the 1990s, health informatics systems have emerged as a powerful factor in the education of health professionals, as well as health consumers. This is enabling a new stance in which information system management can be seen at a higher level, whereby information management includes information system management. This integrating notion helps to associate the disciplines of educational theory and health informatics. To discuss the role of health informatics we will consider 4 components (Fig. 1).

## Health informatics in the planning and delivery of health care

There are diverse roots to health informatics systems.<sup>5-8</sup> A prominent one, due to the administrative structure and power relations in Canadian health care institutions, is the support of administrative functions in hospitals, which led to the implementation of financial, accounting, payroll and inventory control systems in hospitals. The resulting systems were closely modelled after similar applications in other industries. In the form of admission–discharge–transfer systems, they took on more specific medical content.

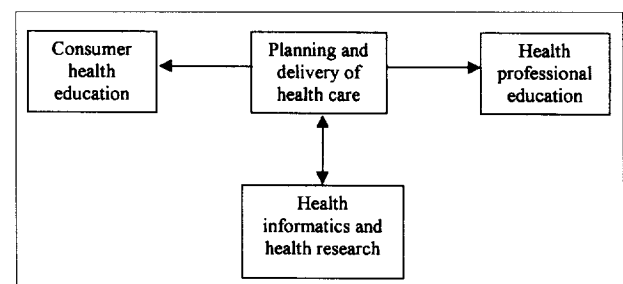


Fig. 1: The 4 components of health informatics.

Another widely successful approach was the conversion of the MEDLARS system of the National Library of Medicine of the United States to MEDLINE, which made the core of scientific medical literature in vastly improved efficiency accessible from around the world.

Another root is population registries, such as for patients with chronic diseases or need for continuous surveillance. Models were provided by personnel information systems in certain industries, which led to such systems as cancer registries. Naturally, these systems became more person-specific and began to develop medical content by registering diagnoses, disease stages, treatments, laboratory values, and so on.

A fourth root of health information systems stems from the need to automate laboratory investigations, starting in the 1960s. As soon as computers were used to automate analysing equipment, the next logical step was to integrate these systems into laboratory information systems that support laboratory medicine from specimen acquisition to result presentation, and with such ramifications as inventory control and work preparation.

Work in electrophysiology provided another important incentive to employ computers. It led to improved acquisition, communication and interpretation of biosignals, which started in cardiology, electrophysiology and nuclear medicine and are now widely used in all areas of intensive care.

The imaging disciplines, in particular nuclear medicine, diagnostic radiology and pathologic anatomy, finally provided an incentive to develop applications for imaging. This eventually allowed not only the extraction of feature information from images through computer processing but provided imaging information on the basis of new biosignals, giving rise to the development of previously unavailable information sources in the form of computed tomography, magnetic resonance imaging, ultrasonography and positron emission tomography, with a marked reduction in danger and discomfort for patients.

These noninvasive imaging modalities are an example of the benefits of fundamentally new approaches. Analogous effects were owing to the logical next step: the attempt to combine the distinct systems that had resulted from these disparate roots into a synergistic, comprehensive whole. This thrust led to the develop-

ment of comprehensive population health information systems and to integrated hospital information systems. Networked regional health information systems with an electronic patient record, which contains all information about the health care of an individual across his or her lifespan, appear increasingly possible. In the future, there will be increasing access to high-quality data that will require a portfolio of skills to integrate its analysis for care management review and the development of a continuing learning environment for care improvement and innovation.

A parallel and complementary thrust was the quest for decision support systems in the 1960s that used the information provided by the other components, in particular, laboratory and drug information systems, to directly support and mimic medical interpretation and medical decision-making. These automated interpretations took various forms. Initially, statistical and deterministic approaches prevailed. These were joined by computer-based models and simulation approaches. Both led to heuristic approaches, evolving into a large field of medical "artificial intelligence." Even if these systems did not gain direct application in hands-on patient care, they yielded important insights into decision-making in health and led to widely applied components embedded into surveillance and imaging systems. Without these insights, we would not have electrocardiogram systems able to tabulate electrocardiographic measurements or intensive care systems flagging dangerous constellations.

These endeavours are the incentive for a specific field of health informatics research and the support of health research through health informatics.

### **Health informatics research and health research**

Health informatics research is directed at the principles underlying the construction of the variety of information systems used in health. It comprises constructive and analytic components and yields insights that are of general importance to health and health care. Not surprisingly, constructive as well as analytic approaches span a large intellectual domain from manipulation of data through to data integration and decision support associated with comprehensive information systems.

Constructive investigations include the develop-

ment of efficient and effective algorithms for use in such diverse applications as the processing, analysis, compression and interpretation of biosignals, imaging and video information, encryption, error detection and error correction, the linkage and analysis of large disjunct databases, and the analysis of medical texts and expressions.

At a higher level of complexity, the design and construction principles of comprehensive health information systems are subject to experimentation and investigation. Here the concern is for the principles that allow systems not only to function correctly, efficiently and effectively toward a defined goal, but also for the principles that allow for the construction of correct systems. This includes the concern for systems that are constructed in such a way that they can be applied to different application domains without having to be rebuilt from scratch. This line of work has led to general systems for documentation and reporting, for image construction and analysis, for generalized expert systems and interpretation systems, generalized statistical analysis systems, generalized hospital departmental systems. Associated with this concern is the concern to minimize side effects, such as undesirable impact on the work habits or the cognitive structure of health care practitioners, or the avoidance of loopholes for intruders, attackers or abusers of such systems. Another facet of this concern is the appropriateness of human interfaces, interfaces that make the power of information systems available, regardless of the location of a legitimate user, while excluding abusers, and interfaces that require minimal training.

Analytic components of health informatics research include the investigation of the health care environment in which information systems are to be applied and the assessment of the information systems themselves. Among others, this work has led to insights into details of health care practices, and the acquisition and modification of cognitive structures of health care practitioners that were previously unavailable. At the same time, it has led to incentives for the development of constructive "meta approaches," that is, constructive approaches directed at analysing and constructing the constructive approaches themselves. An example is the development of computer simulations<sup>9</sup> of the application of

computer-based information systems in health: health information systems are often extremely complex, very expensive and profoundly intrusive. A hospital information system may require investments in the order of several millions of dollars, it has to be introduced over a period of months or years, and it requires training of hundreds of persons. Such systems cannot be introduced in the manner of a controlled trial into a sample of institutions. But it is possible to build computer models that incorporate selected aspects of such systems and allow assessment of the impact of the information system on such aspects. These approaches provide generalizable insights into health and its determinants, the functioning of health care and health care systems.

The advances in health informatics research also have had an impact on health research. As well as supporting data manipulation and optimizing how such information can be accessed and used, there is an important support to clinical research information management. To plan and conduct a clinical research project, which may include collaborations between different clinical sites, is a complex process of information management. Models of processes that are common among studies enable software to support different components such as protocol design, patient characterization for possible trial inclusion and study monitoring, as well as tools to support trial management and complex analysis.

### **Support of consumer health**

The spread of powerful computers among a large and rapidly increasing segment of the population, and their interconnection through the Internet and millions of powerful servers, has brought an entirely new and largely unexpected quality to health and health informatics, and is effecting changes that we are only beginning to fathom. Essentially, it provided a vehicle to tie the general population in a new way into the system of health provision, health maintenance and health care.

According to many assessments, health care is among the foremost reasons for resorting to the Internet. Numerous dedicated sites have emerged, offering health literature, general advice, access to direct medical consultation, health assessments, the purchase of drugs, information on specialized treat-

ment facilities and, perhaps most importantly, access to the community of persons afflicted by specific diseases or health problems. Cancer patients can consult other cancer patients and can get information of those people's experiences with specific treatment facilities or care providers. Beyond affecting the outcome of health care measures, one way or another, these opportunities significantly enable afflicted persons to be in a position of control, a position of choice among alternatives beyond anything conceivable so far. Thereby, they profoundly alter the relationship from that of a patient and a provider, to one on more equal terms, perhaps that of client and professional. This situation, which especially emerged over the last 5 years, will continue, it will accelerate, and it will require an evolution in attitude and behaviour of the health professional beyond "bedside manners." This poses a challenge to the education of health professionals.

### **Medical informatics and education of health professionals**

The effects of medical and health informatics on health professional education are as profound and demanding of change as those on health consumers and clients. The effects reach far beyond the occasional use of computers in technology-assisted learning for health professionals. This is not to say that these applications of computer-based information systems to education are unimportant. It is important that we are able to substitute imaging databases for work on cadavers or microscopes in the education of students. It is important that we can offer virtual reality systems to teach skills in the execution of complicated surgical interventions. It is equally important that we can provide stimulating, engaging communication environments and thereby allow students to interact intensely from their home with other students, mentors, and experts in pursuit of their educational goals.<sup>10</sup> But the demands on education brought about by health informatics go beyond that.

Health professionals and students have to learn how to deal with the new kind of patient, how to build on the new opportunities of accessing information supporting investigation, treatment and planning and how to use this information to best advantage. A basic knowledge is essential concerning the capabili-

ties and limits of information systems, their construction principles, their desirable and undesirable effects. This includes knowledge about data and data qualities, about the representation of abstract concepts in data, about the architectural components of information systems, and about principles for their assessment and hence selection.

They also have to gain knowledge about the practical use of these systems. In some instances, demonstration will suffice, but in key activities, such as information access and use from literature databases and patient records, thorough hands-on training is desirable. Finally, students should be cognizant of the professional, legal and ethical implications of the use of such systems.

Most challenging is the impact of this new information environment on the way we learn both as students and as professionals. The new ability to access current knowledge, critique it and then communicate will considerably affect the culture of the teaching organization and how medicine is practised on a day-to-day basis. This is a very important and exciting area of health informatics research, which will require intensive collaboration between experts in education theory and cognition and experts in system design, providing experts who can work at the interface of design and theory, recognizing the interdisciplinary complementarity that is necessary for health informatics to be effective as a discipline.

### **Required health information infrastructure for medical education**

What kind of infrastructure is required to accommodate the implications of health informatics on medical education? At a very basic level, it is the availability of an appropriate selection of information systems in the basic science and clinical departments. Many of these will serve overwhelmingly for routine applications, such as patient care delivery. In addition, they could serve in application demonstrations in health professional education.

To support hands-on professional training, a number of computer laboratories are desirable in addition. Laboratories for training in information retrieval from literature and factual databases could be associated with medical libraries. These may also be useful

for training in such areas as anatomy or cytology by accessing appropriate imaging databases.

It is certainly conceivable that these laboratories could also serve for hands-on training for professionals (nurses, doctors, administrators), in the use of the information system of the hospital if the system has a client server architecture utilizing standard computers as interfaces. In many cases, hospital information systems will still have a different architecture and may therefore require separate training laboratories. These, however, are desirable to train new personnel in their use, and they could then double for the training of health professionals.

With the demand for laboratory space, however, comes the demand for teaching staff. Again, some of this role can be filled by experienced professional users of these systems: librarians in the case of information retrieval from literature databases, administrators for the demonstration of admission-discharge-transfer systems, electrophysiologists for the demonstration of electrocardiogram interpretation systems, etc. As a rule, however, these people cannot convey the unifying principles behind these systems.

Thus, it is highly desirable that medical faculties include academic units for medical informatics. This recommendation was made in the early 1980s by the American Association of Medical Colleges.<sup>11</sup> It has yet to be implemented in most Canadian medical faculties. In contrast, medical informatics has been a mandatory part of medical education in Germany since 1973,<sup>12</sup> and all but 1 or 2 medical faculties have appropriate academic units. These units have to advance research along the broad phalanx of medical informatics and provide the integrating principles in health professional education.

But the infrastructure requirements do not stop there. Specific adjudication capacity is required by the nature of health informatics research: the combination of constructive, engineering approaches with pronounced mathematical and computer science components is specific to health informatics and cannot be substituted by expertise, e.g., in the social sciences basis of health systems research. Health informatics adjudication committees have been in place in many countries since the 1970s or at least the 1980s, including Germany, the United States and The Netherlands. They are not in place in Canada.<sup>13</sup> The

effect is that health informatics research proposals meet with difficulties in getting funded, and have to be disguised as something they are not in order to get funding. Provision of this capacity may be the most important infrastructure requirement. The time of establishment of the Canadian Institutes for Health Research is the appropriate time to amend this deficiency of the Canadian health research environment.

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