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Viewpoint ■

Science and Practice:
A Case for Medical Informatics as a Local Science of Design

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Abstract Because scientific research is guided by concerns for uncovering ''fundamental truths,'' its time frame differs from that of design, development, and practice, which are driven by immediate needs for practical solutions. In medicine, however, as in other disciplines, basic scientists, developers, and practitioners are being called on increasingly to forge new alliances and work toward common goals. The authors propose that medical informatics be construed as a local science of design. A local science seeks to explain aspects of a domain rather than derive a set of unifying principles. Design is concerned with the creation, implementation, and adaptation of artifacts in a range of settings. The authors explore the implications of this point of view and endeavor to characterize the nature of informatics research, the relationship between theory and practice, and issues of scientific validity and generalizability. They argue for a more pluralistic approach to medical informatics in building a cumulative body of knowledge.

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The relationship between theory and practice has been a source of conflict across many disciplines. Scientists and practitioners work in different cultures and are guided by different goals, priorities, and philosophies. Furthermore, the time frame for scientific research is guided by concerns for uncovering ''fundamental truths,'' whereas design, development, and practice are driven by immediate needs for practical solutions. In medicine, however, as in other disciplines, basic scientists, developers, and practitioners are being called on increasingly to forge new alliances and work toward common goals. This paper articulates a particular point of view concerning the nature of scientific progress in medical informatics. We propose that medical informatics can be construed as a local science of design. A local science seeks to explain aspects of a domain rather than derive a set of unifying principles. Design is concerned with the creation, implementation, and adaptation of artifacts in a range of settings. In this paper, we explore the implications of this point of view and endeavor to characterize the nature of informatics research, the relationship between theory and practice, and issues of scientific validity and generalizability. This leads us to argue for a more pluralistic approach to medical informatics in building a cumulative body of knowledge.

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A Local Science

Medical informatics lives equally in both the world of practice *and* the world of science. As a science, it is concerned with the structuring and representation of biomedical knowledge and models of information processing in human beings and computers.[1] Practice in medical informatics focuses on the design and implementation of systems and tools that facilitate the delivery of health care and can be used to train health care practitioners as well as support biomedical research. There has been much discussion concerning the relative importance of the practical and scientific goals of medical informatics. Certain sciences, such as the physical sciences, are conventionally thought to be concerned with uncovering and codifying reductionist universal truths. However, there are differing philosophical views on what constitutes a science. Following diSessa,[2] let us assume that there is a class of phenomena that is exceptionally rich and diverse such that there may be no single set of principles to encompass it in its entirety. This description is characteristic of a range of sciences, including biology and medicine.[3,4] Medical informatics, like medicine, draws on different kinds of knowledge from a wide range of sources, each having its own set of organizing principles. The landscape of phenomena is simply too complex and diverse to be reduced to a single set of universal principles. This may reflect the current state of medical informatics or may be an inherent attribute of this discipline.

Medical informatics can be construed as a "local science."[2] This is a science where principles simplify and explain parts of the domain of interest rather than provide universal coverage or a unifying set of assumptions. For example, information systems are sufficiently idiosyncratic that the application of a single set of assumptions regarding their development and implementation may cause problems. Nevertheless, local sciences generate principles that have a specific range of applicability, focus our attention on issues and details of importance, and allow us to make meaningful predictions.

A Science of Design

Informatics may be viewed as part of an emerging local science of design.[5] Whether it pertains to architecture or software development, design is concerned with devising artifacts to obtain specific goals. The process of design is commonly viewed as part of an applied domain, perhaps involving the application of scientific principles.[6] In practice, design is strongly bound by domain-specific constraints and grounded in the contexts in which an artifact is to be used. Design is a science that, unlike natural sciences, is not approximately reducible to fundamental principles and yet is guided by abstract principles concerned with function and adaptation. For example, effective human–computer interface design is guided by principles of usability and learnability. In this respect, design is not merely the product of applying principles from other domains of science; instead, it occupies a more central role in developing and testing scientific theories. We accordingly conceive of design not as the end stage in a process of development of implementation but as a process that begins with the inception of a project and continues through cycles of iterative development. In important respects, design continues through the process of adaptation and implementation, as a system is configured and reconfigured to meet the changing needs of the end-user population. Computer systems become deeply interwoven into the fabric of life in a setting, and in the best-case scenario are viewed as seamlessly connected to the ebb and flow of daily work.

Recent research we are conducting applies methods emerging from cognitive science to address theoretic, methodologic, and applied issues involved in introducing technology into collaborative clinical settings.[7,8] An objective of this work is to see how physicians' activities and reasoning processes become iteratively shaped by the use of technology over time and how the technology can be restructured and better adapted to various needs. One such study involves an in-depth investigation of a metabolic day center of a diabetic clinic, which is undergoing computerization that involves the introduction of a pen-based computerized patient record system. The results to date indicate that integration of systems into clinical settings fundamentally change not only how physicians view their daily work practice but also the very process of medical reasoning itself. For example, information systems such as computer-based patient record systems profoundly shape and alter the practice of medicine at many levels, from individual decision-making processes to collaborative interactions with other health care professionals in clinical situations.

One of the goals of a local science of design is to discover what works and then determine why some things work and others don't. A working system is an outcome not merely of technology but of the social and cognitive processes of integrating such a system into the daily workflow. A set of exemplars of working approaches can lead to generalizations and families of theories that can be subsumed within a broad framework. Each successful implementation, as well as each problematic one, can further our understanding of the science of design.

Complexity, Generality, and the Progress of Science

A fundamental goal of informatics is to improve health care by transmitting knowledge for clinical application in a broad range of settings, across computational platforms, and in a timely fashion. When viewed as a science of design, informatics is concerned with generating small-scale theories and principles that may have broad but not universal coverage in guiding development and implementation of artifacts.

How can we build effective bridges between theory and practice? It is clearly important that researchers and practitioners from a range of disciplines collaborate on common objectives. Convergence between science and practical goals has never been easy to achieve. The world of clinical practice needs rapid solutions to pressing problems and cannot afford to wait for definitive experiments and full-blown scientific theories with well-articulated principles. One approach is to begin with small-scale theories specific to a particular problem and somewhat unique to an individual setting.[9] This kind of research has the virtue of being less remote from practice. Similarly, the site of practice becomes a fertile test bed for theory refinement. As a discipline develops theoretic coherence, small-scale theories that stand the test of time can become aggregated into frameworks. A *framework* is a general pool of constructs for understanding a domain but is not well-enough organized to constitute a theory.[10]

What constitutes a contribution to science? Large-scale statistical studies clearly play a central role as hypotheses emerge that need to be tested in that fashion. However, too much research in the social sciences is skewed toward confirmatory hypothesis testing rather than theory development.[11] At a certain point in the evolution of a discipline, case studies are vital sources of scientific knowledge. In our view, such studies continue to provide substantial insights even beyond the initial theory development phases. The case study continues to contribute substantially to medical science. Friedman[12] argues similarly for a broader conception of science in medical informatics.

The heterogeneity and context specificity in medical information systems and clinical settings naturally force us to ask how the science of medical informatics is to succeed if particulars greatly exceed universals? From our vantage point, case studies and in-depth characterizations of specific systems and settings can provide an effective starting point. Indeed, much research in cognitive science and human–computer interaction is based on analyses of a few subjects or single systems.

This raises the thorny issue of generalization. How are we to develop theories of some generality if we test only a few subjects or base our analysis on a single system? The first answer is that we need to develop a basic understanding of any complex phenomenon before testing for generality. The second answer is that in a world filled with idiosyncrasies, particulars, and unique settings, there are a remarkable number of invariants on which we can capitalize once we define them clearly.[13] For example, there are invariant properties of medical tasks, such as diagnostic reasoning and the management of patients with chronic diseases. Similarly, every medical information system has certain invariant features that allow it to perform common functions. Most important, there are numerous invariants of human information processing. This allows us to predict with some measure of confidence that physicians with vastly different backgrounds, working in different settings, will generally experience similar problems when dealing with an unwieldy computer interface.

As medical informatics programs begin to proliferate, this core knowledge is transmitted to physicians, developers, and researchers, thereby leading to emerging standards, paradigms, and expressive languages. In this way, the collection of particulars (derived from specific systems and approaches) advanced by individual institutions leads to the development of notions that are nearly universal (i.e., principles, paradigms, and theories), and they in turn shape the discipline and guide development. There is a cyclic pattern in which universals shape the generation of the particulars of practice, which cause us to rethink the dimensions of the universal (as in the development of vocabulary standards). As we argue in the following article,[13] in the discipline of informatics the particulars and the universals will continue to be of equal importance. Furthermore, the rapid technologic and social changes that are transforming health care and the practice of medicine will necessitate the periodic redrawing of the conceptual boundaries of medical informatics. However, we can profit considerably once the space of particulars (i.e., locally defined features of medical information systems) and their idiosyncratic differences are better understood.

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