The Study of Nursing Informatics

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A framework for organizing the study of nursing informatics is presented. The management and processing of nursing data, information science and nursing science is proposed as an area for study. The premises for such study and the key concepts and relationships are discussed. Nursing informatics would support the practice of nursing and delivery of nursing care.

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The term "informatics" was defined by Gorn (1983) as computer science plus information science. Used in conjunction with the name of a discipline, it denotes an application of computer science and information science to the management and processing of data, information and knowledge in the named discipline. Thus nursing informatics is a combination of computer science, information science and nursing science designed to assist in the management and processing of nursing data, information and knowledge to support the practice of nursing and the delivery of nursing care.

This framework for nursing informatics relies on a taxonomy and definitions of the central concepts of data, information and knowledge put forward by Blum (1986), who defines *data* as discrete entities that are described objectively without interpretation, *information* as data that are interpreted, organized or structured and *knowledge* as information that has been synthesized so that interrelationships are identified and formalized. The management and processing components may be considered the functional components of informatics.

The *management* component of informatics is the functional ability to collect, aggregate, organize, move and re-present information in an economical, efficient way that is useful to the users of the system. The *processing* component of informatics is viewed as being analogous to the processing that is done by nurses (and other clinicians) to make clinical decisions, by researchers to discover and verify knowledge and by theorists to develop nursing theory (Amos & Graves, in press). In practice, processing is considered as a *transformation* of data or information from one form to another form, usually at a more complex state of organization or meaning. There is a progression of transformation of data into information and of information into knowledge. Knowledge is used both in making decisions and in making new discoveries. Both processes—decision making and discovery—can be modelled and represented in computer programs (Hayes-Roth, Waterman & Lenat, 1983; Langley, Simon, Bradshaw & Sytkow, 1987). Thus knowledge can be thought of as being *transformed* into decisions and discoveries (i.e., new knowledge). Building the computer programs to automate or even support transformations between states requires an understanding of (a) the nature and structure of the information to be processed; (b) the transformations that will be useful in nursing; and (c) the algorithms and heuristics (rules of thumb) used by expert nurses to transform information from one state of complexity to another for use in practice, research, and the development of theory. Because nursing informatics deals with the rules and processes that operate on symbolic representations of nursing phenomena, nursing informatics is a legitimate area of study in nursing science.

Premises

The framework for the study of nursing informatics is based on a few central premises: (a) the phenomena of study, (b) the distinctiveness of nursing information, and (c) the integral relationship of informatics to nursing science.

The Phenomenon of Study

The phenomenon of study of nursing informatics is information—data, information and knowledge of nursing. The core of the science of informatics is the commodities that computers process (data, information, knowledge) and not the computer itself (Blois, 1987). Data, information and knowledge can be considered three aspects of a phenomenon that is generically called "information." Information in this generic sense is assumed to be a real entity in the world that has knowable attributes and methods of study (Machlup & Mansfield, 1983). Further, information is an essential phenomenon of study for an information-based discipline such as nursing.

Distinctiveness of Nursing Information

It is further assumed that the data, information and knowledge of nursing are symbolic representations of phenomena of peculiar interest to nursing and that the structure of this nursing information is substantively different from that of other disciplines. These information structures pose discipline-specific problems for the management and processing of nursing information.

This premise is supported by preliminary evidence that the structure of nursing knowledge is different substantively from at least one other health science-related discipline and is reflected in different decision-making strategies. Work on an expert nursing system to support management of acute pain in patients with total hip replacement surgery at the University of Utah has suggested that nurses use different problem-structuring and knowledge-structuring principles than those used by physicians for medical decision making. In addition,

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work on the COMMES system at the Knowledge Center at Creighton University not only suggests that physicians and nurses structure their knowledge differently but also believes that the network of associations and relationships between knowledge elements used by nurses is not readily understood by physicians (Personal communication, S. Evans, November 7, 1988). Still further evidence in support of the premise is offered by studies of expertise and expert-novice differences. These studies indicate that expertise in human beings and computer systems depends on domain knowledge and task-specific strategies rather than on generic problem-solving strategies. These task-specific strategies are used to reduce the problem space, to structure problems and to use the knowledge of the discipline to solve those problems (Corcoran, 1986; Hayes-Roth et al., 1983a).

Relationship of Informatics to Nursing Science

The study of the management and processing of nursing data, information and knowledge—nursing informatics—is considered an integral part of the science of nursing and not simply a branch of computer science or information science applied to nursing. This premise is based on the facts that (a) data and information are symbolic representations of the phenomena with which nursing is concerned, (b) expertise in problem structuring is domain specific and (c) algorithms and heuristics used in solving domain problems are peculiar to nursing. In a paper on medical informatics as a discipline within academic medicine, Warner (1988) defined "medical informatics" as "the study and implementation of structures and algorithms to improve communication, understanding and management of medical information." He pointed out that the key terms of the definition are "structures" and "algorithms" because these elements distinguish medical informatics from other medical specialties where *information content* is the distinguishing feature. This same distinction holds in nursing informatics. Whereas the information content distinguishes the various areas of study within nursing, the information structures and algorithms for processing the symbolic representations are the subject of nursing informatics.

Based on the working definition of nursing informatics as the study of the management and processing of nursing data, information and knowledge, the matrix shown in **Figure 1** represents the conceptual framework. It is intended to serve as a model for understanding the relationships between the concepts and procedural knowledge.

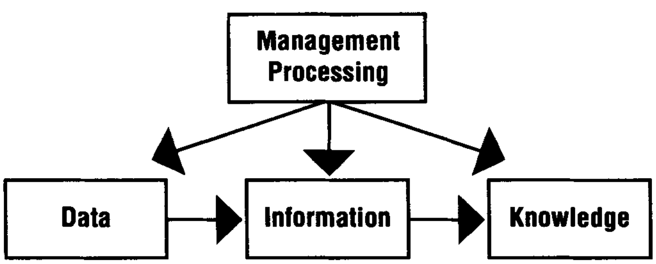

Figure 1. Conceptual framework for the study of nursing information.

Data

A datum is information about a variable. It has the attributes of value and type. The attribute "value" arises because a datum represents something in the real world that has a description or measure. A datum has the attribute of "type" because the thing in the world that is represented has a restricted set of values and there is a restricted set of operations that can be done to manipulate or alter its values. For example, an integer is a type of datum that has a specific and different representation in the computer from a real number type of datum.

Another type of datum is a character string. Alphabetic characters, numbers and, depending on the computer language used, certain special characters such as dollar signs and punctuation marks can be designated a value. This type of datum and the accompanying operations are the foundation of a program with word processing capability.

"Whole text" can also be thought of as a type of data where the unit of processing is a coherent body or "whole" of text. Values and allowable operations for this type of data can be inferred by examining methods that process text as a unit. The allowable range of values for the whole-text type of data is thus at the level of abstracted linguistic meaning.

Two types of applications common in nursing use whole-text data: That where every record contains unique data that are too rich or too ill-defined to be coded or that where the selection and organization of the words into grammatical structures is in itself clinically significant and therefore important to retain in original form for analysis or reporting.

Nursing data issues

In nursing, the development of data applications is just beginning. Currently, the energies of nursing are engaged in identification of the universe of relevant nursing data. Both the whole-person nature of nursing phenomena and the use of multiple conceptual frameworks for structuring nursing knowledge contribute to the difficulties of knowledge development about nursing data. Nursing is concerned with whole person phenomena, yet measures reflecting the wholeness of the phenomena of concern continue to elude the discipline. Questions arise concerning which data elements make up the minimum nursing data set and which data elements are required to capture different nursing diagnostic and/or classification systems, interventions and outcomes. The existence of apparent synonyms and even antonyms in different classification systems raises complex issues of equivalence of definition, measurement and underlying theoretical assumptions.

In the biomedical sciences, computer applications involving data are largely composed of biomedical technology applications such as signal processing and monitoring (Blum, 1986). Few nursing phenomena can be measured using physical instrumentation, however, thus restricting the potential for automated data capture and monitoring.

The complex nature of nursing phenomena poses further difficulties of measurement. Measures must reflect the multidimensional rather than elemental nature of the phenomena. These measures may be quite unwieldy and impractical to use in the immediacy of the clinical moment. To overcome such difficulty, experts in nursing develop a set of heuristics that in their clinical experience are the few most significant indicants of a phenomenon.

Another difficulty that arises in measuring nursing phenomena lies in the fuzzy nature of the phenomena. The property of fuzziness of an entity is the result of the fact that the transition from membership to nonmembership in the class is gradual rather than abrupt (Zadeck, 1978). Examples of fuzziness are the concepts "tall" and "strong." While height can be measured in inches, what is tall? Is a six-foot woman tall? Or is she tall for a woman? One baby has a strong grip: another, weak. The measure of strong and weak grip in the infant is much different from the measure of strong and weak grip in the adult human being. These examples point out that the nurse must not only have solid ideas of the measures "tall" and "strong" but must know something about females and males and about infants and adults. This adds the property of context dependence. Much richness of meaning may be contained in both fuzziness and context of the data. It is important that the richness of the data not be lost in the reduction of data to codes with which the computer can deal more easily.

Because of the fuzziness of category boundaries, expertise in clinical nursing requires development of a repertoire of clinical judgments. These categorizations are difficult to standardize. For example, all nurses may agree on what is clearly severe but categorize quite differently at the boundaries, with one nurse categorizing an observation as "severe" and another nurse categorizing that same observation as "moderate." To categorize them reliably, it forces on the discipline a requirement for rigor in operational definition of observations. Because the study of clinical inference has been so poorly supported in nursing, we don't really know what or how data and information are used by clinicians in measuring complex and fuzzy nursing phenomena.

Knowledge development in the area of nursing data was led by Werley (1987), who pioneered the development of the Nursing Minimum Data Set. Study of data elements required for representing the NANDA classification system and development of a computer system incorporating these data sets was pioneered by Chang and Gilbert (1988) and Chang, Gonzales and Caswell (1988). Other work in progress by Grobe (1988) will assist in the development of a language and a taxonomy, and therefore data elements, representing nursing diagnosis-based interventions. Still other work in the identification of data element sets representing theoretical frameworks in nursing is being done by Ozbolt (1986) and Ozbolt and Swain (1988).

Management

The data management issues are several. In addition to the numerical and coded data that nurses need for measuring physiological and psychosocial parameters, there is a need for whole-text data. While much of the technical work of managing whole-text data can be handled by the computer scientist who is not a nurse, its value and use in nursing deserves further study by nurses to understand its benefits and boundaries for representing nursing phenomena.

Processing/Transformations

Data refer to discrete entities that are objectively described. Data processing implies the transformation of data in raw form to data that is organized and meaningful. Thus the processing of data generates information as a product. While methods for processing of numeric and alphanumeric types of data are well established, processing of whole-text data is in its infancy. Content analysis in one form or another is the major method of processing textual data. Content analysis methods involve the use of standardized procedures to make inferences from the whole text about the sender of the message, the message itself or the audience. The analysis of content of any textual or linguistic whole has to do with measuring "meaning," which in turn has to do with the theoretical framework imposed by the analyst. Although headway in automating such processing is being made, the analyses require expertise in use and interpretion (MacTavish & Pirro, 1984).

Information

Information technology refers to those systems (programs plus computers) used to manage and process information. Information has the attributes of accuracy, timeliness and utility. Utility has the additional attributes of relevance and quality (Goffman, 1981; Saracevic, 1975). Taken together with accessibility, these attributes determine the value of the information. While applications of data rely largely on computational processing, information applications combine data so that meaning is emphasized (Blum, 1986). In applications of information, the emphasis is on efficiency of organization, storage, retrieval and communication rather than on computational processing.

In the health care field, information systems are the primary information technology and are usually named to indicate the discipline or function they support. For example, hospital information systems support hospital functioning and manage accounting information. Clinical nursing information systems (CNIS) and medical information systems manage clinical information required for the practice of nursing and medicine, respectively. Nursing management information systems support nursing administration functions to facilitate the delivery of nursing service.

Nursing Information Issues

The most pressing current issue regarding CNIS issues is modeling the data of nursing (Gordon, 1985; Study Group on CNIS's, 1983; Grier, 1981; Zeilstorff, 1980). Multiple and eclectic conceptual frameworks for practice and classification systems that do not represent the entirety of nursing practice hinder design. In addition, problems arise because differing conceptions of nursing designate different taxonomic labels for nursing's phenomena of concern, parameters for interpretation and related interventions.

Another major issue of importance is the design of information systems to capture and store measures of nursing phenomena for use in various applications versus the design of information systems to document nursing practice. The impact on nursing practice of these designs is an important area of study for nursing informatics.

Management

At its simplest, a CNIS is a systematic, computer-based methodology for providing needed information to the users (i.e., nurses). The role, flow and nature of information in the context of the conceptual and the practice structures of nursing are the major elements that influence design of systems to manage nursing information. At its best, information technology can provide access to the stored knowledge of the discipline and provide a technology for the continuous building of the knowledge base of nursing (Graves & Corcoran, 1988).

Processing/Transformations

The processing of information is much more complex than is the processing of data. Because *information* denotes data to which meaning has been attached by virtue of context or by virtue of having been organized into a structure that carries meaning, processing must somehow deal with meaning.

Processing of information may result in the development of new or different information or the product, *knowledge*. For example, in what might be called research processing, a structured set of rules and procedures is applied to transform information about subjects into knowledge about relationships between the variables of interest. This processing is sufficiently structured to permit the design of research studies by computer programs (Walker & Blum, 1986).

Since information may be processed to generate knowledge, strategies for automating this transformation are an important task of nursing informatics. Understanding how clinical nurses structure clinical problems and how they ask questions of the information system will influence the design of information systems. In addition, the nurse informaticist needs to design information systems that not only support practice but also contribute to the knowledge of nursing.

Knowledge

Knowledge technology is defined as computer systems that manage and process knowledge. Nursing knowledge is simultaneously the laws and relationships that exist between the elements that describe the phenomena of concern in nursing (factual knowledge) and the laws or rules that the nurse uses to combine the facts to make clinical nursing decisions. An example of factual knowledge is knowledge established by research. An example of the laws is an expert clinician's set of heuristics, or "rules of thumb" for practice. Although the two examples seem different, the difference is not crucial to understanding processing operations. Both forms of knowledge deal with laws and relationships that connect the elements of nursing data. What differs is the level of confidence possible about the accuracy of the rules.

Knowledge has the attributes of accuracy, utility (relevance and quality) and type. Although the definitions of accuracy and utility are apparent, the idea of type of knowledge is new. Four ways of "knowing" are acknowledged as being central to nursing practice: (a) empirical, (b) ethical, (c) personal, and (d) esthetic (Carper, 1978). By describing permissible operations for each way of knowing, Kramer and Chinn (1988) elaborated on Carper's patterns of knowing in a way that is analogous to the concept of "data-type" in computational science. Each knowledge pattern is defined by a conceptual description and also by what can be considered "permissible processing operations": parameters, conditions and methods for generating, verifying and transmitting each pattern of knowing. Because of this analogous treatment of ideas of knowledge and data, it is reasonable to assume the attribute of "knowledge-type" and to treat the patterns of knowing as knowledge-types, each having permissible processing operations for the generation, verification and transmission of the knowledge. Study of this knowledge typing in nursing is expected to influence significantly the design of expert decision support systems if in no other way than by adding a dimension along which completeness of the decision set can be evaluated.

To date, knowledge technology is restricted largely to the processing of empirical knowledge. Nonetheless, the exploration of support for managing and processing all knowledge types important to nursing is an important task for nursing informatics.

Nursing Knowledge Issues

Systems that attempt to support clinical inference make imperative an understanding of nursing decision making. Yet, for years, knowledge about nursing decision making has suffered from an earlier categorization as "knowledge about nurses" instead of "knowledge about nursing." It is believed that this faulty categorization in part resulted from the idea that problem solving was a singular phenomenon that was not discipline specific and therefore not "nursing science." It has since been demonstrated that problem solving in a domain is in fact domain knowledge dependent. Evidence of differential structuring and processing of knowledge in decision making by nurses make this topic pressing for nursing scholars.

Management

Two major technologies address the problem of knowledge management: (a) expert systems that are knowledge based and (b) knowledge-base management systems that combine database technology with techniques for reasoning, problem solving and question answering. While information system technology organizes and stores data in ways that can be restructured for optimum presentation, knowledge-base management requires storage not only of data and information but also of rules for attaching meaning, for translating and for combining the information in meaningful ways (Mylopoulos, 1984).

Processing/Transformations

The idea of transformation from one state of information complexity to another can be applied usefully to the processing of knowledge. Knowledge is processed by clinicians, scholars and researchers to generate decisions and new knowledge (discovery). An expert system is a computer program that mimics the deductive or inductive reasoning of a human expert or the outcome of that reasoning process by making inferences from internalized facts and rules (Negoita, 1985). In the health field, expert system technology processes knowledge into decisions about diagnosis and management of clinical problems. Similarly, new discoveries are being made by computer programs that process both numeric and symbolic scientific data using "rules of discovery" (Langley et al., 1987).

Both Iliad™ (Warner, Haug, Bouhaddou, and Lincoln, 1988) and ARKS©, as descirbed in Graves and Corcoran (1988) can be considered knowledge-base management tools. Iliad™ manages expert medical and nursing knowledge and processes it into suggestions about diagnosis and management. ARKS© manages research knowledge about relationships between variables studied together and processes it into theoretical maps. Continued development of tools such as these to support the processing of nursing knowledge will be a major task of nursing informatics.

Conclusion

The task of nursing informatics is to study the structuring and processing of nursing information to arrive at clinical decisions and to build systems to support and or automate that processing. To the extent that human processing of data, information and knowledge can be modelled, these processes can be represented in computer systems and the computer system programmed to mimic the process. When processing can be modelled, we are provided with technologies that can automate the transformation of one state of information into another.

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