Taxonomy Development and Knowledge Representation of Nurses' Personal Cognitive Artifacts

Sharon McLane, PhD, MBA, RN-BC[a] and James P. Turley, PhD, RN[a]
[a]University of Texas School of Health Information Sciences, Houston, TX

Abstract

Nurses prepare knowledge representations, or summaries of patient clinical data, each shift. These knowledge representations serve multiple purposes, including support of working memory, workload organization and prioritization, critical thinking, and reflection. This summary is integral to internal knowledge representations, working memory, and decision-making. Study of this nurse knowledge representation resulted in development of a taxonomy of knowledge representations necessary to nursing practice.

This paper describes the methods used to elicit the knowledge representations and structures necessary for the work of clinical nurses, described the development of a taxonomy of this knowledge representation, and discusses translation of this methodology to the cognitive artifacts of other disciplines. Understanding the development and purpose of practitioner's knowledge representations provides important direction to informaticists seeking to create information technology alternatives. The outcome of this paper is to suggest a process template for transition of cognitive artifacts to an information system.

Introduction

Healthcare practitioners need to have specific clinical data readily available in order to provide safe and effective patient care. Nurses have created clinical summaries about the patients in their care for many years. In most cases, this summary is the result of transcription of data from information sources based upon the clinical condition of the patient and the data needs of the nurse. The transcribed data generally includes results of clinical testing, medication schedule, scheduled nursing tasks, and various non-time-dependent tasks. For the purposes of this research, we have characterized the summary as a PCCAT, or Personally Created Cognitive Artifact.

At the beginning of each shift, the nurse receives report from the departing nurse. The process of receiving report initiates a reflective and reflexive process as the nurse reviews the data communicated during the report and identifies information that is missing and necessary. Identification and organization of the requisite data is highly individualized and based upon the nurse's knowledge, cognition, and data visualization preferences. The summary for each assigned patient enables the nurse to visualize the 'flow of the day' and organize and prioritize care delivery for a group of assigned patients.

Cognitive artifacts are external data displays that augment and influence cognition, understanding, and decision-making (1). Information presented in cognitive artifacts can reshape existing knowledge and influence decisions and actions, illustrating the role of cognitive artifacts in distributed cognition (2, 3). An important construct of cognitive artifacts is that they can relieve the nurse of the necessity of storing data in working memory, serving as a temporary data repository that can be referenced when necessary.

An important first step in this research was to establish that the PCCAT is an example of the cognitive artifact concept. As previously reported, a concept analysis of cognitive artifacts was completed. Subsequent concept analysis of the PCCAT established that it is an instantiation of a cognitive artifact (4). The concept analyses of cognitive artifacts and the PCCAT were completed through the concept analysis process described by Walker and Avant (5).

This study was conducted at a comprehensive cancer center in southeastern United States. The study was approved by the Institutional Review Board (IRB) of the cancer center and of The University of Texas Health Science Center at Houston. Each study participant signed an informed consent document. The study participants were 25 registered nurses who spent at least 50% of their working time providing direct patient care. The study was conducted on three inpatient units: a hematology

stem-cell transplant unit, a thoracic surgery unit, and a neurosurgery and physical rehabilitation unit. These units represented a convenience sample.

Objectives

The PCCAT is an important knowledge representation artifact for nurses. How nurses use the PCCAT, the purposes it serves, and how it supports cognition is only partially understood. The work reported in this paper is part of a larger body of research regarding the knowledge structure, knowledge organization, and knowledge representation of the PCCAT within the practice of clinical nurses. One part of the study was to identify the structure and codify the knowledge displays and other knowledge representations nurses prepare to support their cognitive work and patient care delivery. The purpose of this paper is to describe the knowledge structure and representations identified from study of the PCCAT, the development of a taxonomy, and possible application of this taxonomy to the study of personal cognitive artifacts used by other healthcare practitioners.

Methods

Ethnographic methodology was used to collect data for this research. Multiple data collection methods were used, including deductive and inductive analysis of the PCCAT. Prior to PCCAT analysis and coding, a classification framework was deductively developed. The deductive framework was developed by the principle investigator by incorporating expert nursing knowledge and knowledge gained from an informal review of a number of PCCAT documents. The deductive framework included data elements that were expected to be included on PCCATs, and was categorized into content domains, or classes and subclasses. This preliminary work provided a taxonomic framework, structure, and organization to the process of coding the actual PCCATs. The data collection methodology employed in this research will be reported in detail in a future manuscript.

Over 150 completed PCCATs were collected from 25 nurses who consented to participate in the research. One PCCAT represented the care of one patient for one shift, and each data element on the PCCAT was identified, analyzed, and coded. While the preliminary taxonomy provided a coding framework, the actual data content of the completed PCCATs was much more descriptive, granular, and detailed. Each discrete data element recorded on the PCCAT was identified and coded using an existing code or a new code if the concept had not been previously coded. Spreadsheet software was used to code the PCCATs. Each PCCAT was coded using an individual worksheet. Patient confidentiality was protected through coding and destruction of the original identification data upon completion of analysis.

Collection, analysis, and coding of PCCATs continued until data saturation was achieved. Saturation was defined as redundancy with an absence of new domains and within-domain classes and subclasses (6). The nature of patient care, the unique care needs of individual patients, and the individuality of nurse information needs indicate that it would not be reasonable to expect saturation for discrete data elements.

Reliability was established by recoding each PCCAT to assure all pertinent data elements had been coded. The re-coding process assured that all data contained in the PCCATs had been included in the taxonomy and appropriately coded. After recoding PCCATs to assure complete data entry, the data elements were reviewed and aggregated into physiologic and clinical domains.

After PCCAT analysis and coding was completed, the final stage of data collection was a simulated clinical scenario. Nine study subjects participated in the clinical scenario phase of the study. Each scenario session was conducted with just one subject and the principal investigator. The scenario design focused on two simulated PCCATs. The nurses were asked to indicate data on the simulated PCCAT that had no value and/or that they would not want or expect to be included. Additionally, the nurses were asked to indentify data that was missing from the simulated PCCAT and which they would find necessary to provide safe and knowledgeable patient care. This reflective process often included the heuristics that guided the nurse's data selection decisions and illustrated the importance of the data they required to be present on the PCCAT. The clinical scenario interviews were digitally recorded, transcribed, and coded.

The scenario sessions were conducted for two purposes: 1) to determine that the data recorded on the completed PCCATs was complete, and 2) to assure the resulting taxonomy effectively and completely represented the data nurses need to record on the PCCAT and to provide safe and effective patient care.

Completion of analysis and coding of the PCCATs provided the relational hierarchy of the PCCAT knowledge representation. Protégé 3.4 Beta(7) was used to develop the PCCAT taxonomy using the hierarchical data.

Results

The PCCAT taxonomy includes 14 classes and over 450 unique data elements. Table 1 represents the preliminary knowledge domains, or classes and subclasses.

Table 1: Knowledge Domains of Clinical Nurses

Domains or Classes	**Examples of Sub-Domain Classes**
Activities of Daily Living	Hygiene, Elimination, Mobility…
Admission	Admitting Diagnosis, Reason for Admission, Physician …
Assessment Data	Cardiac, GI, Neurologic Assessments …
Care Interventions	Drains & Tubes, Wound Care, Respiratory Support …
Diagnostic Procedures	Diagnostic Imaging, ECG, EEG …
Discharge Preparation	Patient teaching, Planned Discharge Date, DME Planning …
Fluid balance	Fluid Intake, Fluid Output, Weight …
Laboratory Data	Blood Tests, Cultures …
Medical / Surgical History	Allergies, Comorbidities, Surgical Procedures …
Medication Management	Blood Products, IV Management, Scheduled Medication …
Nurse Consultation	Other Provider, Order Clarification …
Patient Identification	Age, Gender, Name …
Physician & Ancillary Consultations	Consultant, Service …
Surgical History	Surgical Data, Surgical Procedure …

The data elements and classes ranged from high-level concepts such as the status of skin and integumentary integrity, to very granular data such as the presence of a chest tube in the upper right chest tube with minimal air leak and drainage of drained 500cc of serosanguineous fluid during the past shift. The knowledge representation characterized by the taxonomy is a succinct summary of nurses' knowledge application in defining the information necessary to plan, organize, and deliver effective patient-focused care. The PCCAT includes data that describes the patient's current clinical condition, providing immediate access to data that is not readily available or easily accessed. Historically, patient clinical information was often distributed across various locations, such as the paper medical record, forms located in a variety of locations across the inpatient unit and not yet present in the medical record, and in a variety clinical departments such as laboratory, radiology, physical therapy, and others. As hospitals transition from paper to electronic health records, the distribution of clinical data may actually increase for a period of time. Each situation presents healthcare practitioners with the challenge of creating a comprehensive and meaningful snapshot of the current condition and needs of the patient – and recreating the snapshot the next time the healthcare practitioner is responsible for care of the patient. Even after transition to an EHR has been completed, nurses and other healthcare practitioners are often challenged to develop a comprehensive snapshot of a patient's clinical status and needs.

While much of the knowledge representation of the PCCAT relates to requisite nursing care delivery activities, the study of this knowledge representation can be transferred to other healthcare practitioner disciplines. Knowledge structure is apparent in the use of proximity and spatial organization. Chronologies are often created, with the tasks to be completed recorded in appropriate sequences. Working memory support is often incorporated into the structure, such as reminders to follow-up on specific tests, orders, or other interventions. Evidence of the cognitive work of the nurse may also be discerned from the laboratory results, and clinical findings from diagnostic imaging and ECG reports that are recorded on the PCCAT. These data support the nurse in care planning, teaching, and decisions regarding consultation with other members of the care team.

Cognitive artifacts may disclose key information about tasks and functions that are central to the role of the practitioner. For example, the importance of medication management is clearly evident in the knowledge structure of the PCCAT. Medication name

and scheduled administration time are incorporated into the chronology. The immediate availability of allergy information supports the important patient safety check for drug-allergy interactions. Medication compatibility checks were evident as the nurse accessed and often recorded information about administration compatibility of the various intravenous medications ordered for the patient. The chronology also supported the nurse when making notation of the administration of PRN medications, serving as a reminder for later documentation in the medical record. Use of the PCCAT for medication management was the most consistently used function for this artifact.

The knowledge representation of the PCCAT included physician protocol orders to administer blood, platelets, or electrolytes if the laboratory results were less than a specified threshold. In the event of blood product administration, ordered pre-meds were also included. Spatially, this information was generally recorded in proximity to where the nurse recorded laboratory results, thus supporting expeditious implementation of the orders. Reminder of the presence of protocol orders also served as a reminder to obtain the laboratory results as soon as available.

The PCCAT was also used as a temporary repository to record events until the nurse was able to document in the medical record. Examples of the content of these notes included time and topic of telephone calls, patient symptoms, response to pain or other medications, vital signs, and similar data. These notes also included the nurses' intentions to seek consult orders, new orders, or changes to existing orders, as well a notations of response to teaching and question, concerns or issues expressed by the patient or the family.

The content of the PCCAT was representative of the patient's diagnosis and current clinical condition. For example, nurses practicing on the stem-cell transplant unit recorded more detailed data regarding laboratory results and fluid balance as compared the nurses caring for post-operative patients. The surgical nurses demonstrated much more attention to ambulation and physical activity, as this parameter was an important indicator of recovery, whereas the stem-cell unit nurses placed less emphasis on physical activity.

The information recorded on individual PCCATs varied widely between nurses, in addition to the aforementioned differences based upon the clinical service and patient condition. Identifying and defining why these differences were present is the work of later phases of this study

Discussion

The knowledge structure and representation of the PCCAT provides important insight to the cognitive work of the nurse and the cognitive support this artifact provides. It is an external representation of the information nurses need and use to make informed decisions for their patients. The PCCAT also serves as a temporary log or journal of patient care data that the nurse later documents in the medical record or references during consultation with colleagues.

The manner in which the nurse structures data on the PCCAT assists in organization and prioritization of care, and supports the work of clinical decision-making. This structure offers clues to potentially important information visualization indicators. For example, the proximity of laboratory values, protocol orders, and pre-medication orders for blood and blood products serves as a key reminder to gather lab results as early as possible and determine and implement the appropriate intervention. If replacement of electrolytes or blood products is indicated, the nurse can then plan administration of these products in conjunction with other ordered intravenous medications and other nursing care tasks or diagnostic tests.

The taxonomy developed through this work reveals the clinical data nurses find important to have immediately available to support safe and effective patient care. The taxonomy is flexible, supporting the level of granularity appropriate to the task and the individual. The taxonomy is also extensible to accommodate new domains and data elements as necessary.

The foundation of knowledge representation and structure characterized by the PCCAT may serve as a framework for study of cognitive artifacts of other healthcare practitioners. Analysis of the knowledge structure and representation of cognitive artifacts important to other healthcare professionals may provide similar contributions to understanding the cognitive work, information needs, and data

visualization needs of these professionals. Analysis of cognitive artifacts and their contribution to cognitive work is expected to have an even broader application and implication to understanding the information visualization needs of healthcare practitioners within information systems such as the electronic health record. This research has clearly established that careful analysis of cognitive artifacts is critical prior to translating or transitioning artifacts into a new medium or revised format.

Considerable work remains to complete the work of this research. Future work includes 1) validation of the taxonomy for accuracy and completeness with clinical experts and clinical practitioners; 2) while the taxonomy terms depicted in Table 1 represent fidelity to the terminology used by the nurses participating in the study, these terms need to be mapped to and possibly replaced by the language of an existing nursing terminology system; and 3) development of an ontology from the taxonomy and related work of this research is an important step to support design of an effective patient clinical summary for nurses and other healthcare practitioners.

Conclusions

The PCCAT and its taxonomy is a profound indication of the knowledge representation, knowledge structure, and knowledge organization of nurses. Analysis of this the document has led to new understanding and renewed respect for the cognitive work of nurses as they deliver patient care.

The taxonomy provides the framework for development of an ontology, which will lead to an electronic, real-time alternative to the PCCAT using a wireless, hand-held personal device. Prior to embarking on the development of an application, we need to learn more about the nature of the cognitive relationship and support embodied by the PCCAT. Subsequent phases of this research will further explore the knowledge structure, organization, and representation of nurses and the manner in which the PCCAT supports these cognitive functions.

This taxonomy was developed in a comprehensive cancer center in the United States, and as such represents a limitation. Further study is necessary to determine if the taxonomy accommodates the PCCAT needs of nurses caring for the cancer and non-cancer pediatric patient, the non-cancer medical and surgical patient populations, and the cancer and non-cancer critical care environment. Study is also necessary to determine if the taxonomy crosses organizational and demographic cultures.

Further, future research of the differences in the content and use of the PCCAT by highly experienced nurses and recent graduates is needed. Our sample suggests differences, but the sample size is too small to confidently draw conclusions.

Acknowledgements: This research has been funded in part by a grant from the American Organization of Nurse Executives (AONE) Institute for Patient Care Research and Education/Health Research and Educational Trust.

References

1. Patel VL, Kushniruk AW, Yang S, Yale J-F. Impact of a computer-based patient record system on data collection, knowledge organization, and reasoning. JAMIA. 2000 November 7(6):569-85.
2. Zhang J. External Representations in Complex Information Processing Tasks. In: Kent A, editor. Encyclopedia of Library and Information science. New York, NY: Marcel Dekker, Inc.; 2001. p. 164-80.
3. Norman DA. Cognitive Artifacts. In: Carroll JM, editor. Designing interaction: Psychology at the human-computer interface. Cambridge, MA: Cambridge University Press; 1991. p. 17-38.
4. McLane S, Esquivel A, Engebretson J, Smith-Akin K, Wood G, Zhang J, Turley J. Concept Analysis of Cognitive Artifacts. [In review].
5. Walker LO, Avant KC. Strategies for theory construction in nursing. Fourth ed. Upper Saddle River, NJ: Pearson Prentice Hall; 2005.
6. Morse JM, Richards L. Read Me First for a User's Guide to Qualitative Methods. Thousand Oaks, CA: Sage Publications; 2002.
7. Stanford Center for Biomedical Informatics Research. Protégé 3.4 Beta. [Open source ontology editor and knowledge-base framework] 2008. [cited 2009 July 21]; Available from: http://protege.stanford.edu/