

Integration of Nursing Assessment Concepts into the Medical Entities Dictionary Using the LOINC Semantic Structure as a Terminology Model

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Recent investigations have tested the applicability of various terminology models for the representing nursing concepts including those related to nursing diagnoses, nursing interventions, and standardized nursing assessments as a prerequisite for building a reference terminology that supports the nursing domain. We used the semantic structure of Clinical LOINC (Logical Observations, Identifiers, Names, and Codes) as a reference terminology model to support the integration of standardized assessment terms from two nursing terminologies into the Medical Entities Dictionary (MED), the concept-oriented, metadata dictionary at New York Presbyterian Hospital. Although the LOINC semantic structure was used previously to represent laboratory terms in the MED, selected hierarchies and semantic slots required revisions in order to incorporate the nursing assessment concepts. This project was an initial step in integrating nursing assessment concepts into the MED in a manner consistent with evolving standards for reference terminology models. Moreover, the revisions provide the foundation for adding other types of standardized assessments to the MED.

INTRODUCTION

Research has provided evidence that concept-oriented terminologies have a significant impact on data sharing and re-use among heterogeneous healthcare information systems, (1,2) a necessary prerequisite for purposes such as error reduction, benchmarking, and evidence-based practice.

There have been significant efforts both within nursing and the broader healthcare arena to develop reference terminology models upon which to build concept-oriented (i.e., reference) terminologies.(3-7) Work within the European Committee on Standardization (CEN) and International Standards Organization is of particular significance.(8,9) Moreover, recent investigations have tested the applicability of various terminology models for the representation of nursing concepts including those related to nursing diagnoses, nursing interventions, and standardized nursing assessments (e.g., goals,

outcomes) as a prerequisite for building a reference terminology that supports nursing concepts.(10-13)

The purpose of this project was to build upon that work by using the semantic structure of Clinical LOINC (Logical Observations, Identifiers, Names, and Codes) (12) as a terminology model for the integration of standardized assessment terms from two nursing terminologies into the Medical Entities Dictionary (MED), the concept-oriented, metadata dictionary at New York Presbyterian Hospital.

BACKGROUND

Semantic Terminology Model: LOINC

LOINC is a public domain set of codes and names intended for electronic reporting of laboratory test results.(11) The semantic structure of LOINC includes six elements: analyte/component; kind of property measured or observed; time aspect of the observation or measurement; system/sample type which contains the analyte or component being observed; type of scale of the measurement of observation; and type of method used to obtain measurement. More recently, LOINC has expanded to include names of clinical observations through the work of the Clinical LOINC Committee. Bakken et al. extended the Clinical LOINC definitions of the six elements and demonstrated the utility of the LOINC semantic structure as a terminology model for standardized assessments.(11) Consequently, standardized assessment terms from the Omaha System and Home Health Care Classification (HHCC) and several research instruments were incorporated into the LOINC database. Table 1 summarizes the Clinical LOINC elements and extended definitions.

Target Reference Terminology: Medical Entities Dictionary

Our discussion of MED content and structure is limited to those aspects relevant to LOINC and the incorporation of standardized assessment concepts. More extensive descriptions are available elsewhere. (14,15)

Table 1. Clinical LOINC Elements and Extended Definitions

| ELEMENT | DEFINITION |
|-------------------|---|
| Component/Analyte | Attribute of patient or organ system within a patient; name of the scale and item |
| Property | Kind of quantity related to a substance |
| Timing | Interval of time to which the measurement applies |
| System/Sample | Individual or group who is the object of the measurement |
| Scale | Type of scale in measurement |
| Method | Method of completing measurement |

The MED is the institutional metadata dictionary at New York Presbyterian Hospital. It is a concept-oriented semantic network whose backbone is the IS_A subclass relationship. Its logical structure is a directed acyclic graph that implements multiple hierarchies. Software tools have been developed that allow this network to be reliably and readily edited. These tools automatically enforce acyclicity and object-oriented rules of inheritance. Among such tools is a batch editor that accepts a formatted ASCII file of editing instructions. The file itself can be generated programmatically from a Microsoft Access database. In addition, an application programming interface (API) to the MED enables computer programs to efficiently traverse the semantic network in response to user- or computer-generated queries.

Each node in the network is a concept in the dictionary that is viewed as a slot-based frame. The slots and their values, if any, are the defining properties of the concept. There are 2 possible types of slots, string slots whose value is intrinsic to the concept (e.g. its preferred name) and semantic slots that relate a concept to other concepts in the dictionary. An example of a semantic slot is "Part-Of" which would relate an individual laboratory test to the panel of which it is a part. Every semantic slot has a reciprocal which expresses the same relationship, but in the opposite direction. For example, the reciprocal of "Part-of" is "Has-Part".

Each slot has a unique origination point in the MED. This is the most general concept in the MED at which the slot becomes meaningful. Often the origination point is created as an abstract organizing concept and the slot is then inherited by all the concept's descendants. The editing tools referred to above allow a slot's origination point to be easily moved, subject to certain restrictions. In particular, an origination point can always be moved to a more

general concept without impacting any slot values already instantiated in descendants.

All clinical event data that is stored in the central patient database is provided a meta-data concept in the MED that describes the data. An example of clinical event meta-data would be the concept of a particular laboratory test. Laboratory tests have been represented in the MED for the last 8 years. Slots that provide LOINC-related information for laboratory tests were incorporated into the MED approximately 5 years ago.

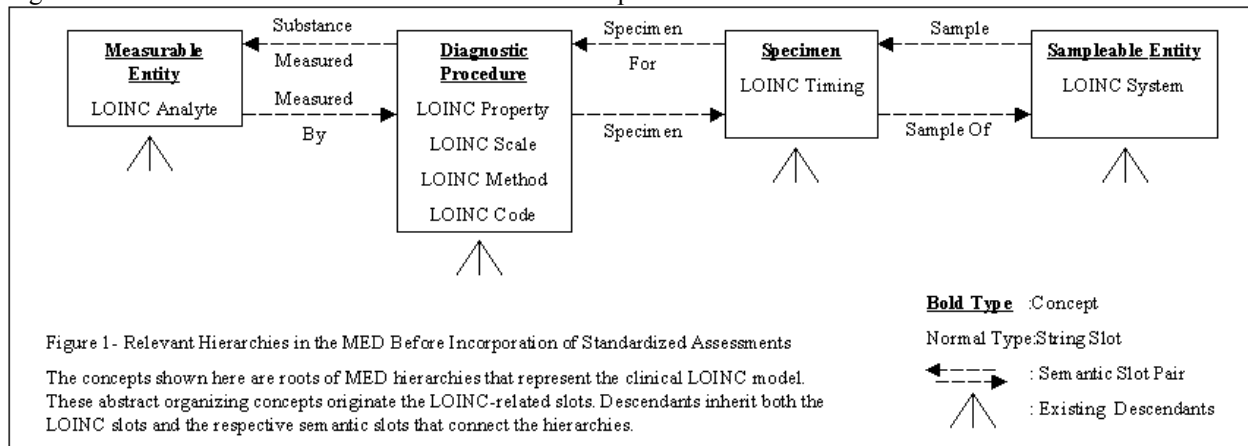
The information related to laboratory tests is distributed over 4 inter-connected hierarchies in the MED that are rooted at the concepts "Diagnostic Procedure", "Measureable Entity", "Sampleable Entity" and "Specimen" (Figure 1). The descendants of "Diagnostic Procedure" are the laboratory tests themselves. The entity that a laboratory test measures, e.g. the "sodium" in a serum sodium specimen is a descendant of "Measureable Entity". The type of specimen submitted for testing, "serum specimen", is a descendant of "Specimen". The entity out of which a specimen is obtained, "serum", is a descendant of "Sampleable Entity".

The distinction between "Specimen" and "Sampleable Entity" is an important one since there is a many-to-one relationship between them. For example, "Urine" is a sampleable entity, but one can obtain from it more than one kind of specimen: spot urines, 24-hour urine collections, etc. This distinction was incorporated into the MED before the formulation of the LOINC specification. The latter does not distinguish between the two concepts into the "System/Sample" part of a fully-specified LOINC name. As it is currently used in the LOINC specification the "System/Sample" name part corresponds to the MED's "Sampleable Entity" hierarchy.

Source Terminologies

Assessment terms were provided by two source terminologies that are currently included in the LOINC database: Omaha and HHCC. The Omaha System includes 40 client problems (Problem Classification Scheme), 62 targets of intervention organized in four intervention categories (Intervention Scheme), and three outcome measures to assess the status of the selected problems (Outcome Model).(16) The assessment model in Omaha is used to evaluate a client's problem on three dimensions: knowledge, behavior and status.

Figure 1. Relevant Hierarchies in the MED Before Incorporation of Standardized Assessments



Each dimension is rated on an ordinal scale of 1-5 (e.g., No Knowledge to Superior Knowledge) (See Table 2). For our project, the client problem and problem dimension represent the name of the assessment and the rating scale, the potential values of the assessment measurement.

HHCC provides a framework and structure for coding home health care nursing services. HHCC includes 145 nursing diagnoses and 166 nursing interventions with four classes of interventions.(17) Each nursing diagnosis has expected outcomes to be achieved by appropriate interventions. HHCC uses modifiers to code the expected outcome as improved, stabilized, and deteriorated. The nursing diagnosis terms represent the name of the standardized assessment and the modifiers are the potential values for the standardized assessment terms that were integrated into the MED.

Table 2. Examples of Standardized Assessment Items

| SOURCE | ASSESSMENT ITEMS | POTENTIAL VALUES |
|--------|----------------------|--|
| Omaha | Nutrition: Knowledge | 1 No Knowledge 2 Minimal Knowledge 3 Basic Knowledge 4 Adequate Knowledge 5 Superior Knowledge |
| HHCC | Activity Alteration | Improved Stabilized Deteriorated |

METHODS

The methods comprised three major steps:

- 1) Analysis of source terminologies and dissection of terms into the LOINC semantic model:

We dissected nursing assessment terms from the two source terminologies into elements of the LOINC model. We organized each item into a Microsoft Access database with the appropriate fields corresponding to the LOINC elements. This provided the organization needed to assess the appropriateness of the semantic structure and to create the batch files for entering the nursing concepts into the MED.

Table 3. Examples of Standardized Assessments Dissected into LOINC Semantic Structure

| | Omaha | HHCC |
|----------------|----------------------|---------------------|
| Component | Nutrition: Knowledge | Activity Alteration |
| Property | Finding | Finding |
| Timing | Point | Point |
| System/ Sample | Patient | Patient |
| Scale | Ordinal | Ordinal |
| Method | Observed.Omaha | Observed.HHCC |

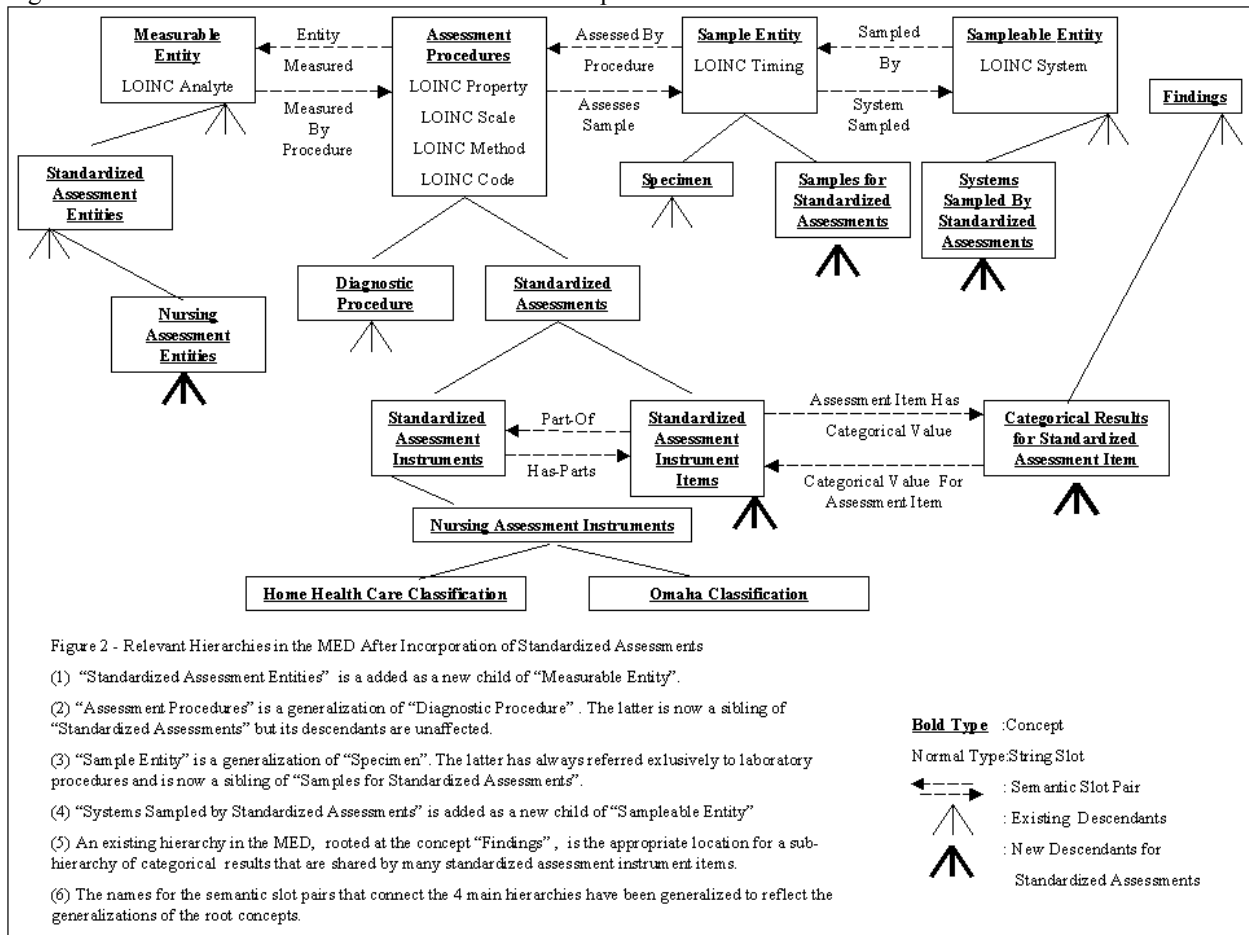
- 2) Modification of the MED semantic structure:

We analyzed each relevant aspect of the MED for its appropriateness for representing the nursing assessment concepts and made revisions as necessary.

- 3) Populating the MED with standardized assessment terms from the source terminologies:

Once the appropriate changes were made to the structure, the nursing assessment concepts from Omaha and HHCC were entered into the corresponding hierarchies using batch files and were linked to LOINC slots and semantic slots in the MED.

Figure 2. Relevant Hierarchies in the MED After Incorporation of Standardized Assessments



RESULTS

All 386 standardized assessment items from the two source terminologies were dissected and successfully entered into the MED after revisions to MED hierarchies and slots. Figure 1 depicts the relevant hierarchies that relate to the Clinical LOINC specification and the inter-connecting semantic slots before incorporation of standardized assessment terminology. Figure 2 depicts the same hierarchies after modification.

DISCUSSION

When performing high-level modifications in the MED, of prime importance is that the meaning of existing concepts that have already been stored in the patient database should not be changed. Therefore, patient-specific laboratory events and their components must retain the same slots and slot instantiations (such as the substance measured and the specimen). On the other hand, abstract organizing

concepts are not patient-specific metadata. Accordingly, "Diagnostic Procedure" can now be viewed as a subclass of a more general concept that we introduce, "Assessment Procedures". This now allows introduction of standardized assessments as a subclass of the new more general organizing concept. The origination point of LOINC-related slots and semantic slots are moved up from "Diagnostic Procedure" to the more general concept. As a result, all existing diagnostic procedures remain unchanged but the slots in question are now bequeathed to all assessments that will be added to the MED.

In a similar fashion we made "Specimen" a child of the more general "Sample Entity" which became the new origination point for the LOINC Timing Code as well as the relevant inter-connecting semantic slots.

The measurable entities in standardized assessments and the systems sampled by standardized assessments are introduced simply as children of the existing "Measurable Entity" and "Sampleable Entity",

respectively. The new concepts automatically inherit the appropriate LOINC-related slots.

The names of the inter-connecting semantic slots were modified to improve their intelligibility without changing their meaning.

Finally, since the items in the Omaha and HHCC standardized assessments use a controlled vocabulary of ordinal values one can exploit an existing hierarchy in the MED that describes the results of assessment procedures. We implemented the linkage between the assessment items and the ordinal values through the introduction of a new semantic slot pair, which automated navigation between the value of an item and the item without need to parse a natural language string.

CONCLUSION

This project was an initial step in integrating nursing assessment concepts into the MED in a manner consistent with evolving standards for reference terminology models. Although the LOINC semantic structure was already used to represent laboratory measures in the MED and the utility of the LOINC semantic structure as a terminology model for representing assessment concepts had been demonstrated, we needed to refine selected aspects of the MED. Such revisions were needed to accurately represent the semantics of the source terminologies and to maintain the meanings of the laboratory measurement concepts already represented in the MED. Of prime importance, our approach allowed us to benefit from the strengths of the LOINC semantic structure and the functionality of the MED.

REFERENCES

1. Brown PJB, Price C. Semantic-based concept differential retrieval & equivalence detection in Clinical Terms Version 3 (Read Codes). Proc AMIA '99 Annual Symposium. Philadelphia: Hanley & Belfus, Inc.; 1999. p. 27-31.
2. Cimino JJ. From data to knowledge through concept-oriented terminologies. J Am Med Inform Assoc 2000; 7:288-297.
3. Bakken S, Button P, Hardiker NR, et al. On the path toward a reference terminology for nursing concepts. In: Chute CG, editor. IMIA Working Group 6 Conference on Natural Language and Medical Concept Representation. Phoenix;1999.
4. International Council of Nurses. ICNP Update - Beta 1 Version. Geneva, Switzerland: International Council of Nurses; May, 1999.
5. Danish Institute of Health and Nursing Research. Telenurse continues to the year 2000 as TelenurseID-

ENTITY: Integration and Dissemination of European Nursing Terminology in Information Technology. WHO Collaborating Centers for Nursing/Midwifery Development Newsletter. 13:5-6, 1998.

6. Ozbolt J. Toward a reference terminology model for nursing: The 1999 Nursing Vocabulary Summit Conference. NI 2000; adis. p.267-276.
7. Hardiker NR, Rector AL. Modeling nursing terminology using the GRAIL representation language. J Am Med Inform Assoc 1998 5(1):120-8.
8. Ehnfors M, Hardiker N, Hoy D, et al. CEN/TC 251 Short Strategic Study. Systems of concepts for nursing: a strategy for progress. Final Report: European Standardisation Committee (CEN); 1999.
9. International Standards Organization. Proposed Scope of Work: Integration of a reference terminology model for nursing. Geneva, Switzerland: International Standards Organization; 1999.
10. Bakken S, Cashen MS, Mendonca E, et al. Representing nursing activities within a concept-based terminologic system: Evaluation of a type definition. J Am Med Inform Assoc 2000 7:81-90.
11. Bakken S, Cimino JJ, Haskell R, et al. Evaluation of the Clinical LOINC semantic structure as a terminology model for standardized assessments. J Am Med Inform Assoc 2000 7:529-538.
12. Bakken S, Parker, J., Konicek, D, & Campbell, K. An evaluation of ICNP intervention axes as terminology model components. Proc AMIA Annual Symposium. Philadelphia: Hanley & Belfus, Inc.; 2000. p. 42-46.
13. Bakken, S., Warren, JJ, Lundberg C et al. An evaluation of the utility of the CEN categorial structure for nursing diagnoses as a terminology model for integrating nursing diagnosis concepts into SNOMED. MedInfo 2000 submitted.
14. Cimino JJ, Hripcsak G, Johnson SB and Clayton PD. Designing an introspective, controlled medical vocabulary. In Kingsland LW, ed. Proceedings of the Thirteenth Annual Symposium on Computer Applications in Medical Care. Washington, DC; November, IEEE Computer Society Press, New York, 513-518, 1989.
15. Cimino JJ, Clayton PD, Hripcsak G, Johnson SB. Knowledge-based approaches to the maintenance of a large controlled medical terminology. J Am Med Inform Assoc, 1994 1(1):35-50.
16. Martin, K.S., & Scheet, N.J. The Omaha System: Applications for community health nursing. Philadelphia: Saunders; 1992
17. Saba, V.K. Home Health Care Classification (HHCC): Nursing Diagnosis & Nursing Interventions. <http://www.sabacare.com>