Model Formulation ■

Development of a Provisional Domain Model for the Nursing Process for Use within the Health Level 7 Reference Information Model

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Abstract **Objective**: Since 1999, the Nursing Terminology Summits have promoted the development, evaluation, and use of reference terminology for nursing and its integration into comprehensive health care data standards. The use of such standards to represent nursing knowledge, terminology, processes, and information in electronic health records will enhance continuity of care, decision support, and the exchange of comparable patient information. As part of this activity, working groups at the 2001, 2002, and 2003 Summit Conferences examined how to represent nursing information in the Health Level 7 (HL7) Reference Information Model (RIM).

Design: The working groups represented the nursing process as a dynamic sequence of phases, each containing information specific to the activities of the phase. They used Universal Modeling Language (UML) to represent this domain knowledge in models. An Activity Diagram was used to create a dynamic model of the nursing process. After creating a structural model of the information used at each stage of the nursing process, the working groups mapped that information to the HL7 RIM. They used a hierarchical structure for the organization of nursing knowledge as the basis for a hierarchical model for "Findings about the patient." The modeling and mapping reported here were exploratory and preliminary, not exhaustive or definitive. The intent was to evaluate the feasibility of representing some types of nursing information consistently with HL7 standards.

Measurements: The working groups conducted a small-scale validation by testing examples of nursing terminology against the HL7 RIM class "Observation."

Results: It was feasible to map patient information from the proposed models to the RIM class "Observation." Examples illustrate the models and the mapping of nursing terminology to the HL7 RIM.

Conclusion: It is possible to model and map nursing information into the comprehensive health care information model, the HL7 RIM. These models must evolve and undergo further validation by clinicians. The integration of nursing information, terminology, and processes in information models is a first step toward rendering nursing information machine-readable in electronic patient records and messages. An eventual practical result, after much more development, would be to create computable, structured information for nursing documentation.

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As electronic communications and data storage become increasingly important in health care, national and international efforts must collaboratively establish a robust and safe infrastructure for health care information. A key component of this infrastructure is health care data standards. National governments have adopted many of these standards or recommended them for adoption for use in their health systems. To assure the validity of the standards as representations of knowledge and information for patient care and public health, professional disciplines must each establish the standards for the information that their practitioners collect and record.

A series of Nursing Terminology Summit Conferences held annually since 1999 at Vanderbilt University in Nashville, Tennessee, has promoted and contributed to standards for nursing information on an international level.[1,2] During the Nursing Terminology Summits, experts in the areas of nursing terminologies, terminology models, health care standards, and health care modeling techniques have harmonized their efforts and knowledge to develop models for nursing data in electronic patient records. The long-range

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goal is to make nursing data, information, and knowledge computable for patient care, decision support, and research.

Work at the Summit Conferences and intervening efforts by participants have used vocabularies recognized by the American Nurses Association,[3] including the International Classification of Nursing Practice,[4] to test evolving terminology models[5] as bases for an eventual reference terminology[6] and to evaluate the feasibility of representing nursing content in the Health Level 7 (HL7) Reference Information Model (RIM).[7,8] Other international standards into which nursing terminology standards must be integrated include the relevant sections of the CEN ENV 13606[9] and of the OpenEHR work.[10] Fortunately, those responsible for both of these initiatives have adopted the HL7 RIM as a basis for further development. It has, therefore, been a priority to focus some of the standards-developing effort in nursing on consistency with the HL7 RIM. Accordingly, this article reports the exploratory efforts of working groups at the Summit Conferences to assess the feasibility of several approaches to representing nursing information in the HL7 RIM.

Background: Representing Nursing Domain Knowledge in the HL7 RIM

Health Level 7 is a standards development organization accredited by the American National Standards Institute, a constituent organization of the International Standards Organization (ISO). HL7 has international affiliate members, and its focus increasingly is on developing international standards. The mission of HL7 is to provide standards for the exchange, management, and integration of data that support clinical patient care and the management, delivery, and evaluation of health care services.[7] HL7's RIM is a comprehensive, non-discipline-specific, object-oriented information model of patient care and of the providers, institutions, and activities involved.[11] The HL7 RIM represents the relevant concepts in health care for which information needs to be available and processed and their mutual relationships.[11] The HL7 RIM is described using the Unified Modeling Language (UML), an object-oriented analysis and design method for developing information systems.[12,13]

At the top level, the HL7 RIM classes include "Entity" (e.g., any person, institution, material), "Role" (a role the entity normally has, such as "Patient" or "Physician"), "Participation" (the actual behavior of an entity in a specific act), and "Act" (any health-related activity).[11] The "Act" class also has an "Act_Relationship" class, which allows combining as many Activities as necessary, e.g., for sequencing activities or detailing them. Act_Relationship is a "collector" class that allows instances of Act to be "collected" in arbitrarily complex networks in three general ways: (1) *container* (CBC contains Hct, Hgb, etc.), (2) *rules* (care plans, protocols, etc.), and (3) *judgments* (diagnoses). Most classes have subclasses. All classes have specific characteristics (the attributes and values). Classes are related to each other via the relationships. Specialization (adding characteristics) and cloning (duplicating classes and their characteristics) make it possible to create representations of these classes tailored to specific care settings, patient categories, and professional domains. This must be done carefully, however, to assure overall consistency with the RIM and to provide interoperability of information within and between information systems.[11]

A basic issue in integrating nursing data standards with general standards for health care data within the HL7 RIM is to define the nursing domain.[14] This article reports early attempts to model the nursing domain in the context of the HL7 RIM. Participants selected two representations of the nursing domain for modeling and mapping to the HL7 RIM. The first was the representation of the nursing process as a dynamic series of phases[15] including the following:

- Data collection or assessment
- Diagnosis
- Identification of goals or desired outcomes
- Planning of interventions
- Implementation of treatment and care
- Evaluation

Each of these phases usually has additional steps. For example, Diagnosis implies interpreting data, relating data to other data, formulating hypotheses, determining additional data needed to test hypotheses, and so on.

The second representation of the nursing domain to be mapped to the HL7 RIM was the very generic Nursing Information Reference Model (NIRM).[14] The NIRM focuses on the information needs of nurses at clinical and higher (more abstract) levels, identifying a hierarchy of nursing information. At the base are atomic facts or findings about the patient. The second level consists of meta-observations such as nursing diagnoses, interventions, and outcomes and of the standardized vocabulary needed for naming them. The third level describes the aggregation of nursing diagnoses, interventions, and results into statistical reports at the institutional level for such purposes as management and quality improvement. Finally, the fourth level selects and aggregates nursing data from many institutions into population reports for public health and policy at national and international levels. Thus, the NIRM describes types of domain information in the nursing profession and its purposes. The challenge is to map such domain information, with its peculiarities, to the more comprehensive, non-discipline-specific health care information models.

The concept of nursing as a dynamic process and the hierarchy of information in the NIRM model provide useful perspectives on the nursing domain. Modeling these representations of the nursing domain consistently with the HL7 RIM will lay the groundwork for data exchange and semantic interoperability in electronic health records. For example, using this approach, the Dutch perinatology project combined the information management of general practitioners, midwives, medical specialists, and nurses.[16]

Methodology for Model Formulation

In working groups at the Terminology Summits, the authors analyzed and modeled the nursing process in three ways. First, they developed a process-oriented description of the dynamics of the workflow during the nursing process. Second, they developed a structural description to illustrate the major data classes in the nursing process. Third, they made a hierarchical analysis of the different layers of knowledge or ontologies in nursing. Finally, they used the

example of nursing findings for a small-scale validation. They used the UML for modeling.

Modeling Nursing as a Dynamic, Problem-solving Process

Creating a UML activity diagram of the nursing process was the starting point for the modeling work. Participants followed UML conventions to depict the dynamic nature of the nursing process (Fig. 1). Accordingly,

- The different activities performed in the phases of the nursing process are portrayed as "activity states" (a rounded rectangular shape).
- Clinical decisions are "branches" (diamond shapes).
- The beginning and end of the process are visualized as "start and stop states" (black dot, and black dot with white spot, respectively).
- The workflow is represented via the lines with arrows that relate the states and decisions.

Additional features of activity diagramming were not used in this exploratory work.

Depicting Nursing Concepts and Relationships: Structural Analysis

To explore and model the fundamental concepts and relationships that define the information used at each phase of the nursing process, the working groups used a UML class diagram. In contrast to an activity diagram, a class diagram shows a set of classes, interfaces, collaborations, and their relationships.[12] Attributes and operations can be made visible in a class, although depicting them increases the complexity of the model and thus decreases readability. Class diagrams are used to model the static design view of a system, supporting the functional requirements, i.e., the services the system should provide to the end users.[12]

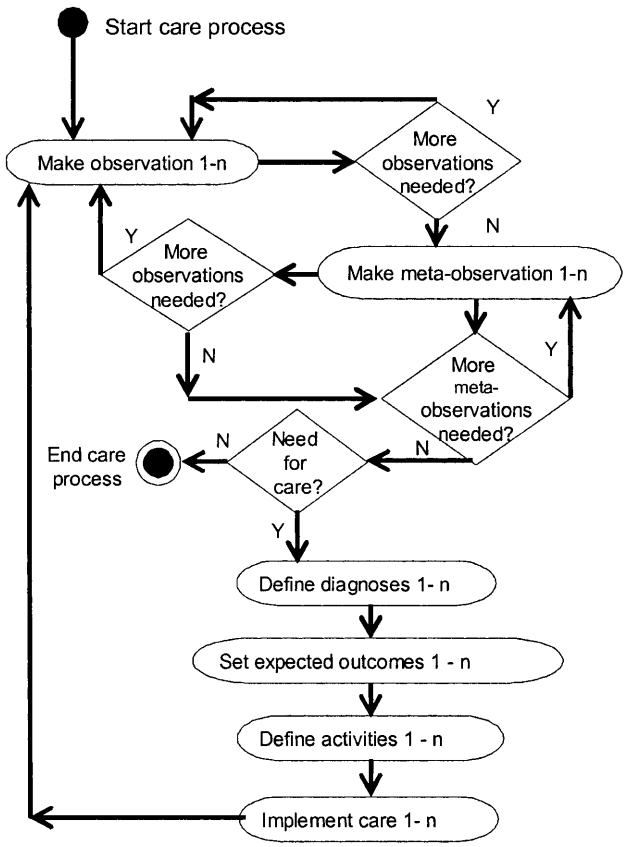

Figure 1. An activity diagram of the nursing process as a problem-solving approach to patient care.

Based on the general notion of the nursing process, and the first and second layers of the NIRM, the working groups constructed a class diagram that illustrates several classes for the objects in the nursing process (Fig. 2). Next, they modeled relationships between these classes and some multiplicity (cardinalities). Cardinalities are the number of elements in a set.[12] For this domain model for nursing, the number of elements was limited for simplicity. In a more detailed depiction, the number of elements might be determined by such considerations as the number of findings required to make inferences or the number of interventions needed to achieve a goal.

After developing the class diagram, the group mapped its conceptual content to the HL7 RIM classes. For this mapping, they explored the attribute "cd" (code) of several RIM classes, as well as the "value" attribute of the RIM class "Observation." This work addresses a major issue of the Terminology Summits: a correct use of nursing terminology within the HL7 RIM.

Modeling the Hierarchical Organization of Nursing Knowledge

To explore the mapping of hierarchical nursing knowledge to the HL7 RIM, the groups used the example of the "Findings" class in the UML domain model of Figure 2. The best match was with the HL7 RIM class "Observation." The class "Findings" in the domain can be specialized into subclasses of particular examples, such as areas of concern (feelings of the patient, activities of daily living, or circulation). Participants agreed that "Findings" can account for many different types of data the nurse gathers from the patient, and no exhaustive listing was made at this stage. However, examples were chosen to follow up the procedure of defining subcategories, sub-subcategories, and an even further detailed nesting to represent the domain information.

Thus, the domain of nursing was organized into a hierarchical representation of knowledge. This looks very much like the organization of domain knowledge for the development of expert- or knowledge-based systems.[17–19] The key features are that the knowledge is organized in a systematic way and that hierarchical aspects of the knowledge are made visible. The working groups decided to model the nursing assessment phase only as a first example for the modeling approach.

Mapping Domain Information Models to the HL7 RIM

The next step was to map the contents of the structural class model and the nested model to the HL7 RIM. The approach was to use Domain Message Information Models (D-MIMs).[11] A D-MIM is a method of representing concepts from a particular clinical or administrative domain as classes, attributes, and roles in the HL7 RIM. Goossen et al.[16] posited that the D-MIM functions as a bridge in the communication gap between health professionals and informaticians. The groups constructed D-MIMs to describe the semantic

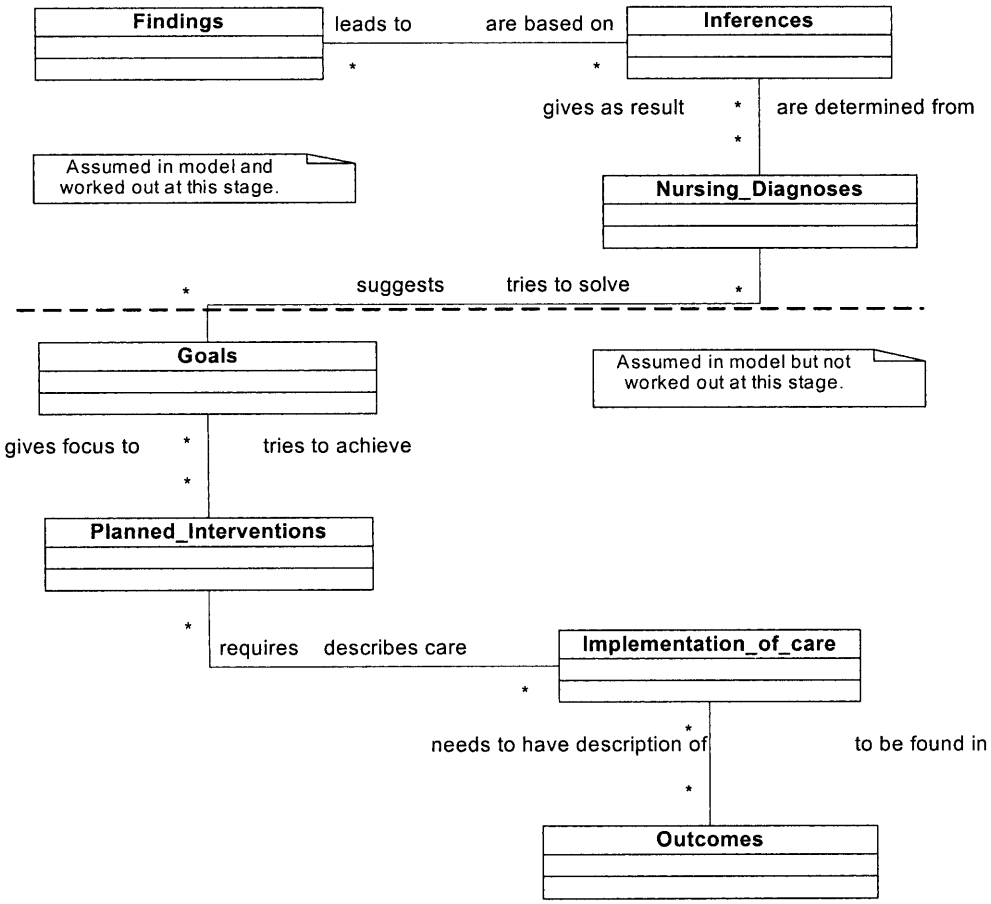

Figure 2. Class diagram that models the nursing process in Unified Modeling Language.

structure of the information contained in the nursing process and NIRM. All the specialized classes representing the "Findings" in the assessment phase of the nursing process were considered instances of the RIM class "Observation." As an exercise, some examples from the hierarchy and domain models were mapped to the HL7 RIM. On the assumption that the appropriate RIM class is indeed "Observation," the group compared attributes and values for each information item in the "Findings" category. These comparisons resulted in a table (Table 1) containing the classes and vocabulary for the domain information on one hand and their corresponding RIM class and attributes on the other hand. This effort provided a small-scale validation of the approach with examples from two distinct classifications and vocabularies that are relevant for nursing practice.

It would be critically important to have a nursing terminology model that organizes the terms that would populate the value set of instances of "Observation."[5] Here, the linkage between the terminology model and the information model becomes crucial for a further systematic mapping from the domain to the RIM.

Results: Description of the Models

Process-oriented Model

The working group described the nursing process in an activity diagram as depicted in Figure 1. Because names for objects represent activities, they are verbs. It is important to distinguish the names used in the activity diagram properly from the names of the classes in the structural model, which are nouns. These activities representing the dynamics of the nursing process include "make observation," "make meta-observation," "decide on need for care," "define diagnosis," "set expected outcome," "define activities," and "implement care." From the moment care is delivered, new observations will take place, making the process recursive, until the client achieves a condition in which there is no further need for care, and outcomes can be determined.

Starting on top with the Start State, Figure 1 reads as follows:

- Observations 1-n are made until there is no need for further observations. That condition is depicted in the diamond that branches to "yes more observations," leading to additional observations, or to "make meta-observation."
- The meta-observation can be any result of clinical reasoning or judgment, including "everything is OK," a "hunch," or the identification of a nursing diagnosis. This continues until the nurse has completed data collection and assessment, so it is possible to have several meta-observations (1-n).
- Following these meta-observations, the nurse can decide whether care is needed.
- If there is a need for care, the nurse develops a care plan, including defined nursing diagnoses, expected outcomes, and activities (interventions), all preferably named from the standardized nursing terminologies.

Table 1 ■ Examples of Mapping Nursing Terminology to HL7 RIM Classes and Attributes

Finding Example	Code	HL7 RIM Class	Mapping to HL7 RIM Classes and Attributes
Transferring oneself	ICF d420	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = ICF • Value = d 420 transferring oneself
Moderate performance	ICF qualifier for performance xxx.0 NO difficulty xxx.1 MILD difficulty xxx.2 MODERATE difficulty xxx.3 SEVERE difficulty xxx.4 COMPLETE difficulty xxx.8 not specified xxx.9 not applicable	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = ICF performance qualifier • Value = moderate difficulty in performance
Skin	ICNP 1A.1.1.1.10.1	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = ICNP • Value = ICNP 1A.1.1.1.10.1
Altered	ICNP 1B.5.1	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = ICNP • Value = ICNP 1B.5. altered
Sense pressure Yes/No	No coding found for sensing pressure Perception has code 1A.1.1.2.1.1.2.2 and Tissue Compression has code 1A.1.1.1.10.3.1 Yes has code 1B.1.1, and No has code 1B.1.2 Limited could be coded with 1B.1.1.2.: "Yes, to some degree"	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = the subset from ICNP as shown in the second column • Value = the actual situation that is observable at one point in time but described with the subset of codes from column two only
Color of skin	No coding found Therefore, a special value is used for the time being until a better coding system is found	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = Normal pink or brown, reddish from pressure • Value = Reddish (this then is an example of an instantiation for a particular patient that has a red skin at one point in time)
Pressure ulcer	ICNP 1A.1.1.1.10.3.5.3 for pressure ulcer and Yes code 1B.1.1, or No code 1B.1.2	Observation	• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = all possible codes from ICNP • Value = 1A.1.1.1.10.3.5.3 & 1B1.2, indicating there is no pressure ulcer
Wound Yes/No	1A.1.1.1.10.3.6 for wound, and Yes has code 1B.1.1, and No has code 1B.1.2		• HL7 RIM ClassCode = OBS (Observation) • MoodCode = EVN • Code = ICNP • Value = 1A.1.1.1.10.3.6 & 1B1.1, indicating there is a wound present

- Next, the nurse delivers care, leading to new observations. Some of those are evaluative meta-observations relating to care effectiveness and outcomes.
- The process repeats until there is no further need for care or observations. That situation is illustrated with the "stop state," which is the end of the care process.

Structural Class Model

Figure 2 shows a preliminary structural class model, presented in Unified Modeling Language notation using Microsoft Visio Professional 2002 software.[20] The working group identified the following subclasses, representing one possible way of documenting during the different phases of the nursing process: findings, inferences about findings, nursing diagnoses, goals, planned interventions, implemented interventions, and outcomes. We did not name any subclass "assessment," because the multiple meanings of the concept assessment would introduce ambiguity in the use of the HL7 RIM. Note the differences in naming compared with the activity diagram: these are nouns.

The first class presents all the findings that nurses document as patient data: history, observations, measures, answers to questions, and subjective information from patients. The second class describes the inferences nurses make about these findings or data, to represent the documented hunches, hypotheses, and differential diagnoses (i.e., the described conclusions or meta-observations). This is based on the nursing process description, with one addition from the NIRM to represent the decision-making component. It might be that some early findings will immediately lead to determining the nursing diagnoses. However, other nursing diagnoses probably will need additional findings, measures, or tests to be certain. It is important that during the inferences, the intermediate results can be documented. Therefore, the inferences are a class allowing storage of data similar to the

findings class but include personal reminders for the clinician. Other classes are added to represent the actual nursing diagnoses, goals, interventions (planned and carried out), and the (final) outcomes. The diagnoses, goals, and outcomes all are meta-observations in the activity diagram. Also, performing care interventions can be documented in the information systems.

Figure 2 only visualizes the classes, their relationships, and the multiplicity (cardinalities) as many to many. Correct multiplicity and attributes need to be added in a later stage. The asterisks in Figure 2 indicate that for the time being, it can be many relationships, and no further constraints have been identified.

Hierarchy of Nursing Domain Knowledge

To further detail the observations, specialized sets of classes for "Findings" were identified. "Findings" represent such information as a client's answers to questions; observations by the nurse; measurements such as body weight, degree of pain, blood pressure, and temperature; and score on mental status examination. These "Findings" can be grouped in many different ways, so long as they represent a systematic organization of nursing knowledge, using standardized nursing terminology and codes when the distinct values (measurements) are expressed. The group recommends that such a structure or model of "Findings" be determined through further testing. An example for the nursing domain is to determine the subcategory "Findings of Skin" as one relevant subcategory of findings in nursing care. A further nesting is identified in the different functions and characteristics of the skin. Additional subcategories would be necessary to describe findings about movement, activity, sensory perception, and so on. Next, some of these sub-subclasses are further nested into relevant subparts. As part of this project, the group members are continuing to test the structure of the model with an example, namely, assessment of the risk for pressure ulcers.[21]

This organization of nursing knowledge can be done in such a way that relevant terminology can be hosted and fit with the HL7 RIM. Thus, the domain analysis gives a basis for integrating nursing items in the HL7 RIM to ensure nursing data can be communicated in an interoperable manner.

This organization of the knowledge about what findings are relevant for particular patients, or for nursing care in general, is necessary for the determination of relevant subclasses in the domain. The example in Figure 3 is one example of a structure representing findings. The representation in Figure 3 and the examples of "Findings" shown here are a pragmatic solution rather than a logically correct one. We assume that "Findings" form the context for a value and that we determine that something we find out about skin color is to be considered a "Finding." This is similar to other domain information such as a diagnosis or family history. Other representation forms exist, such as *clinical document architectures*,[22] to represent complete clinical documents such as assessment forms, discharge letters, and clinical templates or *archetypes* to represent clinical information.[23]

If it is clear how findings can be organized in a structure and/or a model, it will be possible to specialize the subclasses to meet the various data needs for client categories or nurse specialties. Figure 4 is an example of a tentative way to organize three levels of findings. Subclasses inherit the characteristics of the higher class, similar to the genus–species principle in classifications. This is illustrated with the arrows with open heads. Attributes of the metaclass "Findings" include a code set, in which any terminology or classification can be selected to define nursing content. One example is the World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF).[24] To represent a problem with mobility, for example, the nurse could use the ICF code "d420" for "transferring oneself." The ICF now has a scaling axis (modifier), which can be applied to give a value for the level of transferring for one particular patient, e.g., this patient has a moderate performance, which is up to half of the scale of a total performance problem (i.e., $25 < V < 50\%$).

Similarly, the nurse could code skin problems using items from the International Classification for Nursing Practice[3] (ICNP), although to define a nursing diagnosis, descriptions from several axes must be combined. In this example, we simply combine the focus and the judgment axes for findings of the skin. The code set would then be the ICNP. The area of concern—"Skin"—can be coded with 1A.1.1.1.10.1, and the value for the judgment can be "altered," which has code 1B.5.1. Alternatively, "Pressure Ulcer" is listed in the ICNP focus axis. Similarly, other characteristics, from other ICNP axes 1B to 1H, such as the judgment, anatomic location, or duration, can be added to the classes.

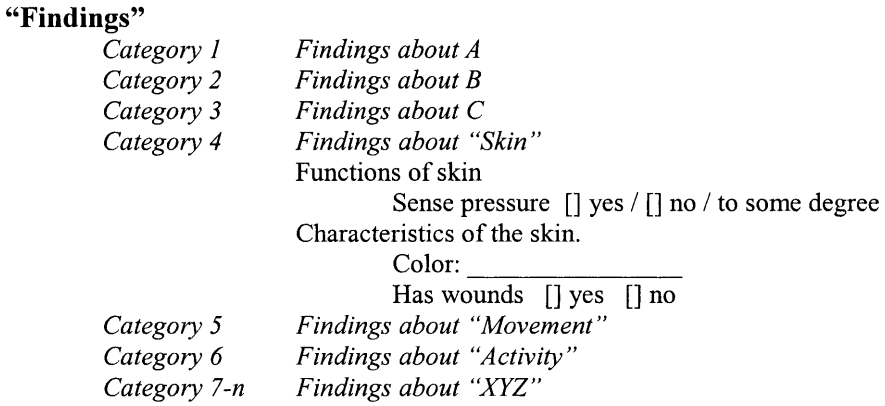

Figure 3. Example of a nested organization of nursing knowledge.

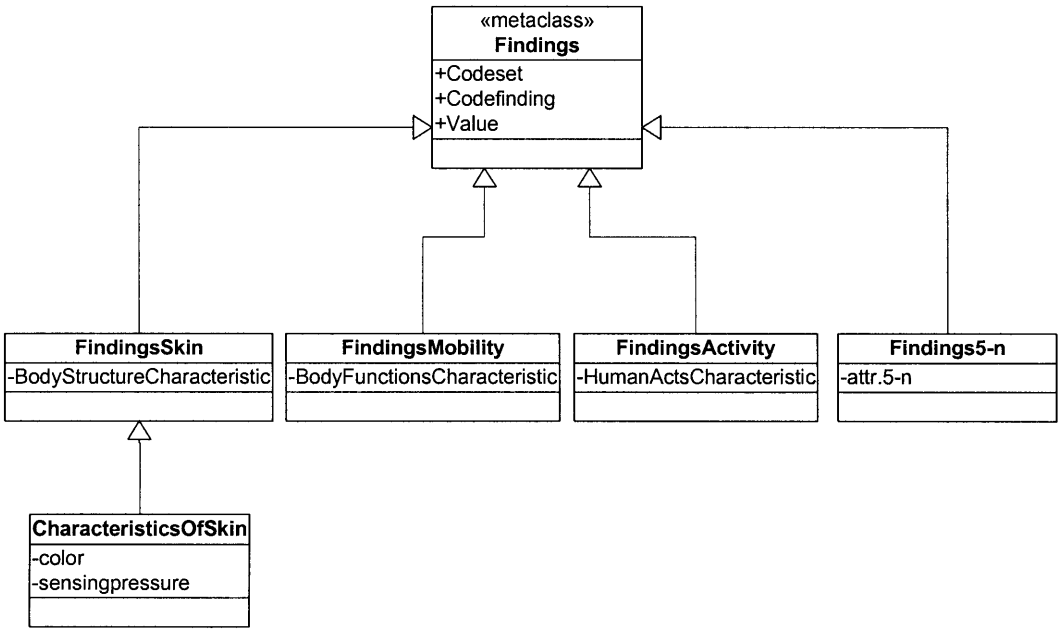

Figure 4. Domain model to nest categories and subcategories in the findings section of the nursing process.

For the details of "Skin," the following codes can apply. No coding has been found in the ICNP focus axis for "sensing pressure." Alternatively, "Perception" has code 1A.1.1.2.1.1.2.2 and "Tissue Compression" has code 1A.1.1.1.10.3.1. "Yes" has code 1B.1.1, and "No" has code 1B.1.2. For the skin example, some value for "degree" is necessary. The concept of "Limited" can be coded using ICNP value "Yes, to some degree" with code 1B.1.1.2. A percentage for some degree, available in the ICF, is missing here. For colors, there is no coding in the ICNP, and whether skin colors are coded elsewhere has not been investigated at this time. "Wound" has ICNP code 1A.1.1.1.10.3.6 and the "Yes" and "No" codes have been described and can be reused.

Similarly, for other "Findings" sections a subclass can be made. In Figure 4, for example, for Mobility, Activity, and several other categories, subclasses are summarized in "options Findings 5 to *n*," where *n* stands for the number necessary to adequately describe the domain.

Results: Validation via Mapping Nursing Domain Information Models to the HL7 RIM

For a small-scale validation, the working groups mapped the model of Findings to the HL7 RIM class "Observation." Several examples from the rubric "Findings" in the nursing process thus populate the sets of codes or values of instances of Observation. The class Observation has multiple attributes, only four of which were used in our example. The attributes in our exercise were as follows:

- The ClassCode expresses in HL7 that we are using an "Observation" class (OBS).
- The MoodCode value "event" (EVN) illustrates that we are discussing something that has already happened, a fact in the real world. (The "event" could have been further qualified by the attribute "time stamp," but we did not pursue that in our example. Other values of the MoodCode could show, for example, that a particular intervention is planned but not yet executed. MoodCode thus offers possibilities for representing the dynamic phases of the nursing process.)
- The third attribute, "Code," is used to define a particular coding system for the specified observation. The coding system can be a large-scale terminology, such as SNOMED-CT with multimillion terms, or a simple code set with only two codes such as "red" and "pink." In our examples, we continue to work with codes from ICF and ICNP.
- Finally, the fourth attribute is the one that makes the HL7 RIM "Observation" class differ from the more general "Act" class, by adding the option of documenting a specific value for an observation at a point in time. The value can be selected as one of several possible data types such as numbers, text strings, codes, or pictures.

Arriving at a single, standard representation of nursing domain concepts and terminology in the HL7 RIM "Observation" class is complicated by the multiplicity of options for correct representation. Table 1 contains several examples showing how even in the same code set, different combinations of attributes and codes can represent the same complex concept accurately. As discussed above, the example about transferring (Table 1) has the ICF as code set. ICF code d420 is the actual code for transferring, and the value attribute of "Observation" can be used to represent the score on the ICF performance scale. In the example, the current situation documented is "moderate performance," which is the score of one patient on the scale at one point in time. In a similar way, ICNP codes can be mapped to RIM and used to represent the focus of an observation (e.g., skin) and the resulting value (e.g., altered, which is the judgment of the clinician; Table 1).

The example of "Wound" in Table 1 uses ICNP in the HL7 code attribute to indicate that all ICNP codes are valid for any observation. This broadens the usability of the class and the

code system. Then in the value field, the codes 1A.1.1.1.10.3.6 meaning "wound" and code 1B1.1 meaning "yes" are entered as the entry in the nursing documentation. The combination of these two codes in the value field indicates there is a wound present.

Discussion and Conclusion

The nursing profession is challenged to link developments in evidence-based practice, knowledge development, process optimization, terminology, and reference information models, among other areas. The linkage between nursing domain information, in particular, terminology, and the HL7 RIM described here is necessary to achieve comparable data on nursing care for the communication and exchange of nursing information. This report has described a tentative and very generic domain model for the nursing process, using the UML activity diagram and the UML class diagram for dynamic behaviors and data structures, respectively. In addition, some details for a hierarchical organization of domain models are included.

The purpose of the domain analysis and domain models is to allow an appropriate mapping from the specified domain to the Health Level 7 Reference Information Model. These models should be further improved and validated by experts and clinicians in nursing with respect to the workflow and content needed for these models and the way the content should be structured. For instance, the activity diagrams should be expanded to show "swim lanes" that define responsibilities for roles and parallel processes for all professionals and services involved in care. In addition, experts in UML, information models in general, and the HL7 RIM developers should further test these draft models, adding details and checking for consistency. Figures 2 and 4, especially, need further work with respect to identifying the multiplicity. Also, ID codes of each class, subclass, constraints, and all other HL7 attributes for the RIM class "Observation" must be further detailed and validated with nursing content. In that sense, this report is only the beginning of the work necessary.

Several areas require further exploration and development. The first relates to the number and kinds of classes needed to represent nursing information. Is Figure 2 an adequate representation of the information needed during the nursing process? Is it complete enough to cover all nursing-specific knowledge, data, and terminology that nurses might want to collect and manage in an electronic patient record system? Does the feasibility of mapping "Findings" to the HL7 RIM class "Observation" mean that "Goals and Outcomes" could map similarly? Or alternatively, if there is overlap of nursing goals and nursing outcomes with the classes representing the assessment phase, would it be better to have only one class and to collapse "Findings," "Goals," and "Outcomes" into that class, using the "mood" attribute to differentiate?

The second issue is the determination of an adequate level of nesting. How many levels deep do we need to nest to collect all the necessary patient data in different settings? What are the tradeoffs for the options available? Do we need one basic structure, or can we build upon mini-molecular structures and assemble these together as we like it? How can we best represent the multiaxial classifications such as ICNP and ICF, and the nursing reference terminology model that has a focus, a judgment, and additional characteristics, to the current HL7 RIM "Observation" class? The object-oriented approach suggests that working with small modules is feasible. Each module then becomes a clone or a specialization of a particular class and can be reused (instantiated) as many times as needed. Developing a system could look like shopping in the models supermarket with a shopping list of required objects. "We want an object for skin, an object for mobility, an object for visual capacities, two for the risk for falls and pressure ulcers, one for pain assessment, and an object for describing activities of daily living." In the validation section, we used different levels of detail for the coding and values. What works best with the coding system and the level of granularity in a given situation needs to be further determined, based on the purpose of data collection and communication. From an HL7 RIM perspective, the presented hierarchy of findings in the nursing assessment is simply a matter of "observation vocabulary" and not a situation of different (RIM) concepts and classes. An important question here would be whether we need to distinguish additional features of diagnoses, based on inferences, goals, and outcomes, and "Findings" that are merely "simple" observations.

A third issue that is not solved in this model is the use of nursing terminology and classifications and of evidence-based practice materials such as scientifically reliable and valid scales and/or clinical guidelines that represent best practices. However, at a particular point we need to describe these most granular items and values exactly. The HL7 workgroups on vocabulary and clinical templates provide beginning suggestions for this additional work. An example of such work is discussed in another report that illustrates activities from the templates workgroup of the Nursing Terminology Summits of 2001 and additional ongoing work.[19]

An important and unsolved fourth issue is the question as to what domain materials should be part of the terminology, and what should be part of the information model. Should information about the related factors of a nursing diagnosis go into the terminology, or should that be a part of the RIM? Other work groups in the Nursing Terminology Summits are addressing some of these issues.[25,26] The solutions that emerge to address these issues will affect the models presented here.

As noted in the title of this report, the proposed nursing domain models are provisional. We are not there yet, but the first step has been taken to integrate nursing knowledge, processes, terminology, and information for use in electronic patient record systems. This work has shown that, in principle, it is possible to link a core model of nursing (the nursing process) to a core model in health care (HL7 RIM). This is important for further developments using more detailed patient-oriented approaches and domain-specific information. The perinatology project in The Netherlands illustrates the importance of working with further detailed domain information.[16]

A significant limitation for the material presented here is that we have focused mainly on the assessment, inference, and

diagnostic phases in nursing. An important topic for further work is to look into the other areas of the nursing process, including goals, interventions, and outcomes. That work will open a number of questions. How should we represent nursing goals and nurse-specific outcomes in the HL7 RIM? And how can we represent nursing interventions adequately? Is the "Act" class of the RIM sufficient to contain all kinds of nursing interventions? Are these interventions thus similar to those of health professionals? What about teaching and patient education? Some of these questions are being addressed,[25, 26] but others need attention in the near future.

The authors do not pretend that the approach taken here is the only or the best way to go. However, it proves to be a feasible way of modeling nursing domain information and mapping it to the HL7 RIM. If further work along these lines proves useful and valid, nursing information can be integrated into the larger health information system. The integration of nursing knowledge, terminology, processes, and information into the reference models that are accepted internationally will enable the use of nursing information in electronic patient records and its aggregation for management, knowledge development, and public health.

The practical implications of this work are several. Showing the feasibility of modeling and mapping nursing information to HL7 standards lays the groundwork for further development. Through such work, nursing content can be transmitted and understood in electronic messages and so can be included in templates and clinical documents, among other features of HL7 v3 and other data standards.

We need to continue collaboration and initiatives across countries, disciplines, and various standards organizations to work toward standards to represent and communicate the diversity of health care in our electronic record systems. This contribution shows the relevance and feasibility of such collaboration for the nursing community worldwide.

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