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CHAPTER 17

Advanced Terminological Approaches in Nursing

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OBJECTIVES

1. Describe the need for advanced terminology systems.
2. Identify the components of advanced terminology systems.
3. Compare and contrast two approaches for representing nursing concepts within an advanced terminology system.

KEY WORDS

concept representation

terminology

vocabulary

standardized nursing language

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The failure to achieve a single, integrated terminology with broad coverage of the healthcare domain has been characterized as the “vocabulary problem.” Evolving criteria for healthcare terminologies for implementation in computer-based systems suggest that concept-oriented approaches are needed to support the data needs of today’s complex, knowledge-driven healthcare and health management environment. This chapter focuses on providing the background necessary to understand recent approaches to solving the vocabulary problem. It also includes several illustrative examples of these approaches from the nursing domain.

Background and Definitions

The primary motivation for standardized terms in nursing is the need for valid, comparable data that can be used across information system applications to support clinical decision-making and the evaluation of processes and outcomes of care.

Secondary uses of the data for purposes such as clinical, translational, and comparative effectiveness research, development of practice-based nursing knowledge, and generation of healthcare policy are dependent on the initial collection and representation of the data.

Given the importance of standardized terminology, one might ask, “Why, despite the extensive work to date, is the vocabulary problem not yet solved?”

The Vocabulary Problem

Several reasons for the vocabulary problem have been posited in health and nursing informatics literature. First, the development of multiple specialized terminologies has

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resulted in areas of overlapping content, areas for which no content exists, and large numbers of codes and terms (Chute, Cohn & Campbell, 1998; Cimino, 1998a). Second, existing terminologies are most often developed to provide sets of terms and definitions of concepts for human interpretation, with computer interpretation as only a secondary goal (Rossi Mori, Consorti & Galeazzi, 1998). The latter is particularly true for nursing terminologies that have been designed for direct use by nurses in the course of clinical care (Association of Operating Room Nurses, 2007; Johnson, Bulechek, Butcher, Dochterman, Moorhead & Swanson, 2006; Martin, 2005; Saba, 2006). Unfortunately, knowledge that is eminently understandable to humans is often confusing, ambiguous, or opaque to computers, and, consequently, current efforts have often resulted in terminologies that are inadequate in meeting the data needs of today's healthcare systems. This chapter focuses on providing the background necessary to understand recent concept-oriented approaches to solving the vocabulary problem. It also includes illustrative examples of these approaches from the nursing domain. Note that the word "terminology" is used throughout this chapter to refer to the set of terms representing a system of concepts.

Concept Orientation

An appreciation for the approaches discussed in this chapter has as a prerequisite an understanding of what it means for a terminology to be concept-oriented. Previous published reports provide an evolving framework that enumerates the criteria (Table 17.1) that render healthcare terminologies suitable for implementation in computer-based systems. In particular, it is clear that such terminologies must be concept-oriented (with

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explicit semantics), rather than based on surface linguistics (Chute, et al., 1998; Cimino, 1998b; Cimino, Hripcsak, Johnson & Clayton, 1989). Several previous studies have reported that many existing nursing terminologies do not meet the criteria related to concept orientation (Henry & Mead, 1997; Henry, Warren, Lange & Button, 1998).

Table 17.1 Evaluation Criteria Related to Concept-Oriented Approaches

Atomic-based—concepts must be separable into constituent components (Chute, et al., 1998)
Compositionality—ability to combine simple concepts into composed concepts, e.g., “pain” and “acute” = “acute pain” (Chute, et al., 1998)
Concept permanence—once a concept is defined it should not be deleted from a terminology (Cimino, 1998b)
Language independence—support for multiple linguistic expressions (Chute, et al., 1998)
Multiple hierarchy—accessibility of concepts through all reasonable hierarchical paths with consistency of views (Chute, et al., 1998; Cimino, 1998b; Cimino, et al., 1989)
Nonambiguity—explicit definition for each term, e.g., “patient teaching related to medication adherence” defined as an <i>action</i> of “teaching”, <i>recipient</i> of “patient”, and <i>target</i> of “medication adherence” (Chute, et al., 1998; Cimino, 1998b; Cimino, et al., 1989)
Nonredundancy—one preferred way of representing a concept or idea (Chute, et al., 1998; Cimino, 1998b; Cimino, et al., 1989)
Synonymy—support for synonyms and consistent mapping of synonyms within and among terminologies (Chute, et al., 1998; Cimino, 1998b; Cimino, et al., 1989)

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In order to appreciate the significance of concept-oriented approaches, it is important to first understand the definitions of and relationships among things in the world (objects), our thoughts about things in the world (concepts), and the labels we use to represent and communicate our thoughts about things in the world (terms). These relationships are depicted by a model commonly called the semiotic triangle (Fig. 17.1) (Ogden & Richards, 1923). The International Organization for Standardization (ISO) international standard ISO 1087-1:2000 provides definitions for elements that correspond to each vertex of the triangle:

Concept (i.e., thought or reference): Unit of knowledge created by a unique combination of characteristics—a characteristic is an abstraction of a property of an object or of a set of objects.

Object (i.e., referent): Anything perceivable or conceivable.

Term (i.e., symbol): Verbal designation of a general concept in a specific subject field—a general concept corresponds to two or more objects which form a group by reason of common properties (International Organization for Standardization, 1990).

As specified by the criteria in Table 17.1 and illustrated in Fig. 17.1, a single concept may be associated with multiple terms (synonymy); however, a term should represent only one concept.

Components of Advanced Terminology Systems

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Within the context of the high-level information model provided by the Nursing Minimum Data Set (NMDS) (Werley & Lang, 1988), there has been extensive development and refinement of terminologies for describing patient problems, nursing interventions, and nursing-sensitive patient outcomes (AORN, 2007; Moorhead, Johnson & Maas, 2004; Martin, 2005; Dochterman & Bulechek, 2004; North American Nursing Diagnosis Association, 2008; Ozbolt, 1998; Saba, 2006) including the development of the International Classification for Nursing Practice (ICNP) (Coenen, 2003; International Council of Nurses, 2009). These terminologies are described elsewhere in this text. The main component of more advanced terminology systems, however, is a concept-oriented terminology model or ontology representing a set of concepts and their interrelationships. The model is constructed using an ontology language that may be implemented using description logic within a software system or by a suite of software tools.

Terminology Model

A terminology model is a concept-based representation of a collection of domain-specific terms that is optimized for the management of terminological definitions. It encompasses both schemata and type definitions (Campbell, Cohn, Chute, Shortliffe & Rennels, 1998; Sowa, 1984).

Schemata incorporate domain-specific knowledge about the typical constellations of entities, attributes, and events in the real world and, as such, reflect plausible combinations of concepts, e.g., “dyspnea” may be combined with “severe” to make

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“severe dyspnea”. Schemata may be supported by either formal or informal composition rules (i.e., grammars).

Type definitions are obligatory conditions that state only the essential properties of a concept (Sowa, 1984), e.g., a nursing activity must have a *recipient*, an *action*, and a *target*.

There have been several published reports related to terminology models for nursing (Bakken, Cashen & O'Brien, 1999; Hardiker & Rector, 1998; ICN, 2001), which contributed to the development of an international standard for a reference terminology model for nursing (ISO, 2003).

Representation Language

Terminology models may be formulated and elucidated in an ontology language such as Knowledge Representation Specification Syntax (KRSS) (Campbell, et al., 1998) or Web Ontology Language (OWL) (Rector, 2004). Ontology languages represent classes (also referred to as concepts, categories, or types) and their properties (also referred to as relations, slots, roles, or attributes). In this way, ontology languages are able to support, through explicit semantics, the formal definition of concepts in terms of their relationships with other concepts (Fig. 17.2); they also facilitate reasoning about those concepts, e.g., whether two concepts are equivalent or whether one concept, such as “pain”, subsumes (is a generalization of) another, such as “acute pain”.

Computer-Based Tools

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A representation language may be implemented using description logic within a software system or by a suite of software tools. The functionality of these tools varies but may include among other things management and internal organization of the model, and reasoning on the model, such as automatic classification of composed concepts based on their formal definition, e.g., “teaching medication regime” is a kind of “teaching”.

In addition, the software may facilitate transformation of concept representations into canonical form (e.g., “cardiomegaly of the heart” is transformed to “cardiomegaly” since the location of the pathology is inherent in the concept itself), or support a set of sanctions (i.e., constraints) that test whether a proposed composed concept is sensible (e.g., “decubitus ulcer of the heart” and “impaired normal cognition” are not coherent terms). Other software support may be provided for knowledge engineering, operations management, and conflict detection and resolution.

The extent to which a terminology may be suitable for computer processing has previously been characterized in terms of “generations” (Rossi Mori, et al., 1998). *First-generation terminology systems* consist of a list of enumerated terms, possibly arranged as a single hierarchy. They serve a single purpose or a group of closely related purposes and allow minimal computer processing. *Second-generation systems* include an abstract terminology model or terminology model schema that describes the organization of the main categories used in a particular terminology or set of terminologies. The abstract terminology model is complemented by a thesaurus of elementary descriptors (i.e., terms) and templates or rules (i.e., grammar) for defining how categories may be combined. For example, “pain” and “severe” may be combined into “severe pain”. Second-generation

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systems can be used for a range of purposes, but they allow only limited computer processing, e.g., automatic classification of composed concepts is not possible. *Third-generation systems* support sufficient formalisms to enable computer-based processing, i.e., they include a grammar that defines the rules for automated generation and classification of new concepts. Third-generation language systems have also been referred to as formal concept representation systems (Ingenierf, 1995) or reference terminologies (Spackman, Campbell & Cote, 1997).

Because they were designed primarily for direct manual use by nurses in the process of care or for classification purposes, the majority of existing nursing terminologies (e.g., NANDA, Nursing Interventions Classification [NIC]) can be characterized as first-generation systems. The *beta 2* version of the ICNP provided an example of a second-generation system (ICN, 2001) – this has subsequently been superseded. Advanced terminology systems, i.e., third-generation terminology systems are the focus of the remainder of this chapter.

Advantages of Advanced Terminology Systems

Computer-based systems that support clinical applications such as electronic health records and decision support require more granular (i.e., less abstract) data than that typically contained in terminologies designed primarily for manual use or for the purpose of classification (Campbell, Carpenter, Sneiderman, Cohn, Chute & Warren, 1997; Chute, Cohn, Campbell, Oliver & Campbell, 1996; Cimino, 1998b; Cimino et al., 1989). Advanced concept-oriented terminology systems allow much greater granularity through

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controlled composition while avoiding a combinatorial explosion of pre-coordinated terms, thus, enhancing the ability of computer-based systems to process clinical data for meaningful use.

In addition, as described previously in this chapter, advanced terminology systems facilitate two important facets of knowledge representation for computer-based systems that support clinical care: (a) describing concepts and (b) manipulating and reasoning about those concepts using computer-based tools. Advantages resulting from the first facet include (1) nonambiguous representation of concepts, (2) facilitation of data abstraction or de-abstraction without loss of original data (i.e., “lossless” data transformation), (3) nonambiguous mapping among terminologies, (4) data reuse in different contexts, and (5) data exchange across settings. These advantages are particularly important for clinical uses of the terminology. Advantages gained from the second facet include auditing the terminology system, automated classification of new concepts, and an ability to support multiple inheritance of defining characteristics (e.g., “acute postoperative pain” is both a “pain” and a “postoperative symptom”). Both facets are vital to the maintenance of the terminology itself as well as to the ability to subsequently support the clinical utility of the terminology (Campbell et al., 1998; Rector, Bechhofer, Goble, Horrocks, Nowlan & Solomon., 1997).

Advanced Terminological Approaches in Nursing

Over recent years, there have been a number of initiatives that support the development of advanced concept-oriented terminology systems for the nursing domain. Following a

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brief description of approaches underpinning three of these initiatives (terminology models within ISO 18104:2003, modified KRSS underpinning the original development of SNOMED (Systematized Nomenclature of Medicine) and the OWL representation of ICNP), a nursing term is represented under ICNP and SNOMED CT (SNOMED Clinical Terms) approaches in order to illustrate similarities and differences between representations. A further illustrative example demonstrates one of the potential functions of an advanced terminology system for nursing, i.e., cross-mapping between existing terminologies.

Terminology models - ISO 18104:2003

An international standard (ISO 18104:2003) covering reference terminology models for nursing diagnoses (Fig. 17.3) and nursing actions (Fig. 17.4) was approved in 2003 (ISO, 2003). The standard was developed by a group of experts within ISO Technical Committee 215 (Health Informatics) Working Group 3 (Semantic Content) under the collaborative leadership of the International Medical Informatics Association—Nursing Special Interest Group (IMIA-NI) and the International Council of Nurses (ICN). The model built on work originating within the European Committee for Standardization (European Committee for Standardization, 2000).

The development of ISO 18104:2003 was motivated in part by a desire to harmonize the plethora of nursing terminologies in use around the world (Hardiker, 2004). Another major incentive was to integrate with other evolving terminology and information model standards—the development of ISO 18104:2003 was intended to be “consistent with the

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goals and objectives of other specific health terminology models in order to provide a more unified reference health model.” (ISO, 2003, p. 1). Potential uses identified for the terminology models include to (1) facilitate the representation of nursing diagnosis and nursing action concepts and their relationships in a manner suitable for computer processing, (2) provide a framework for the generation of compositional expressions from atomic concepts within a reference terminology, (3) facilitate the mapping among nursing diagnosis and nursing action concepts from various terminologies, (4) enable the systematic evaluation of terminologies and associated terminology models for purposes of harmonization, and (5) provide a language to describe the structure of nursing diagnosis and nursing action concepts in order to enable appropriate integration with information models (ISO, 2003). The standard is not intended to be of direct benefit to practicing nurses. It is intended to be of use to those that develop coding systems, terminologies, terminology models for other domains, health information models, information systems, software for natural language processing, and markup standards for representation of healthcare documents.

ISO 18104:2003 has undergone substantial bench testing, both during its development and through independent research (Hwang, Cimino & Bakken, 2003; Moss, Coenen & Mills, 2003). The standard was under review at the time of writing for consideration of revisions.

Modified KRSS - SNOMED RT/CT

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A concept-oriented approach was developed, through collaboration between the College of American Pathologists and Kaiser Permanente, based on SNOMED International. SNOMED Reference Terminology (RT) was a reference terminology optimized for clinical data retrieval and analysis (Spackman, et al., 1997) that, along with U.K. Clinical Terms, SNOMED RT has been used as a foundation for a new terminology system, SNOMED Clinical Terms (CT). Concepts and relationships in SNOMED RT were represented using modified KRSS (Campbell, et al., 1998). Concept definition and manipulation were supported through a set of tools with functionality such as (1) acronym resolution, word completion, term completion, spelling correction, display of the authoritative form of the term entered by the user, and decomposition of unrecognized input (Metaphrase) (Tuttle, Keck, Cole, Erlbaum, Sherertz, Chute, Elkin, Atkin, Kahoi, Safran, Rind & Law, 1998), (2) automated classification (Ontylog), and (3) conflict management, detection, and resolution (Galapagos) (Campbell et al., 1998). Table 17.2 illustrates the representation, using generic description logic representation and modified KRSS, of a single nursing activity. SNOMED CT was developed collaboratively by the College of American Pathologists and the U.K. National Health Service (Wang, Sable & Spackman, 2002). SNOMED CT possesses both reference terminology properties and user interface terms. SNOMED CT is considered to be the most comprehensive, multilingual clinical healthcare terminology in the world and integrates, through external mappings, concepts from multiple nursing terminologies and classification systems including: Clinical Care Classification, International Classification for Nursing Practice, North American Nursing Diagnosis Association Taxonomy, Nursing Interventions Classification, Nursing Outcomes Classification, Omaha System, and Perioperative

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Nursing Data Set . SNOMED CT is distributed through the International Health Terminology Standards Development Organisation (IHTSDO). IHTSDO is an international not-for-profit organization based in Denmark whose purpose is to develop, maintain, promote and enable adoption and correct use of its terminology products such as SNOMED CT.

Table 17.2 Possible Representations of the Nursing Activity Concept “Bladder Irrigation”, Using Generic Description Logic Representation and Modified KRSS

Generic Description Logic Representation (with corresponding OWL constructors)	$\text{BladderIrrigation} \equiv \text{Irrigating} \sqcap \exists$ actsOn.Bladder Key \equiv equivalentClass \sqcap intersectionOf \exists someValuesFrom
Modified KRSS Representation	(Define-concept BladderIrrigation (and Irrigating) (actsOn Bladder))

OWL - ICNP

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Outside the health domain, work in relation to the Semantic Web has resulted in an emerging “standard” (i.e., a W3C recommendation) ontology language, OWL (McGuinness & van Harmelen, 2004). OWL is intended for use where applications, rather than humans, are to process information. As such, it should be able to meet the requirements of advanced terminology systems that support contemporary healthcare. OWL builds on existing recommendations such as eXtensible Markup Language (XML) (surface syntax for structured documents), Resource Description Framework (RDF) (a data model for resources), and RDF Schema (a vocabulary for describing the properties and classes of resources) by providing additional vocabulary and a formal semantics. Software, both proprietary and open source, is available for (a) managing terminology models or ontologies developed in OWL (e.g., Protégé (Protégé, 2010)) and (b) reasoning on the model (e.g., FaCT++ (Tsarkov, 2009)). Work within nursing is maturing. For example, ICNP is maintained in OWL – it is a compositional standards-based terminology (Hardiker & Coenen, 2009) for nursing practice that The compositionality of ICNP further facilitates the development of and the cross-mapping among local terminologies and existing classification systems (ICN, 2009).

An OWL representation (in XML) of the nursing activity concept “Bladder Irrigation” is provided in Table 17.3 for comparison with the KRSS representations in Table 17.2.

Table 17.3 Possible OWL Representation (in XML) of the Nursing Activity Concept “Bladder Irrigation”

```
<owl:Class rdf:ID="BladderIrrigation">
```

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```
<owl:equivalentClass>
  <owl:Class>
    <owl:intersectionOf rdf:parseType="Collection">
      <owl:Class rdf:about="#Irrigating"/>
      <owl:Restriction>
        <owl:onProperty>
          <owl:FunctionalProperty rdf:about="#actsOn"/>
        </owl:onProperty>
        <owl:someValuesFrom>
          <owl:Class rdf:about="#Bladder"/>
        </owl:someValuesFrom>
      </owl:Restriction>
    </owl:intersectionOf>
  </owl:Class>
</owl:equivalentClass>
</owl:Class>
```

Advanced Terminology Systems in Practice

Figure 17.5 displays a potential mapping (to the right of the figure) between the NIC concept “Bladder Irrigation” (McCloskey & Bulechek, 2004) and the precoordinated Omaha System concept “Treatments and Procedures: Bladder Care” (Martin & Scheet, 1992). A computer-based reasoner can use the formal definitions of the corresponding composed concepts to infer a hierarchical relationship. The asserted properties for both

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concepts (in the center of the figure) are identical. The existing hierarchy (to the left of the figure) asserts that “Performing” subsumes “Irrigating”. Thus, “BladderCare”, which maps to the Omaha System concept “Treatments and Procedures: Bladder Care”, is a generalization of “BladderIrrigation”, which maps to the NIC concept “Bladder Irrigation.” Hence, the NIC concept “Bladder Irrigation” potentially maps onto the Omaha System concept “Treatments and Procedures: Bladder Care” (but *not* vice versa).

Summary and Implications for Nursing

Previous studies have supported the need for advanced concept-oriented terminology systems that (a) provide for nonambiguous concept definitions, (b) facilitate composition of complex concepts from more primitive concepts, and (c) support mapping among terminologies (Campbell et al., 1997; Cimino, Clayton, Hripcsak, and Johnson, 1994; Chute et al., 1996; Henry, Holzemer, Reilly & Campbell, 1994). Because of the magnitude of resources and collaboration required, the development of advanced concept-oriented terminology systems is a fairly recent phenomenon. However, a number of benefits have been proposed: (1) facilitation of evidence-based practice (e.g., linking of clinical practice guidelines to appropriate patients during the patient-provider encounter); (2) matching of potential research subjects to research protocols for which they are potentially eligible; (3) detection of and prevention of potential adverse drug effects; (4) linking online information resources; (5) increased reliability and validity of data for quality evaluation; and (6) data mining for purposes such as clinical research, health services research, or knowledge discovery.

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The developers of nursing and healthcare terminologies and informatics scientists have made significant progress. From decades of nursing language research, there exists an extensive set of terms describing patient problems, nursing interventions and activities, and nursing-sensitive patient outcomes (AORN, 2007; ICN, 2009; Moorhead, et al., 2004; Martin, 2005; Dochterman & Bulechek, 2004; North American Nursing Diagnosis Association, 2008; Ozbolt, 1998; Saba, 2006). Through the efforts of nursing professionals, new terms have been integrated into large health-care terminologies as demonstrated by nursing informatics research, which are useful for representing nursing-relevant concepts (Bakken, Cimino, Haskell, Kukafka, Matsumoto, Chan & Huff, 2000; Bakken, Warren, Lundberg, Casey, Correia, Konicek & Zingo, 2002; Henry et al., 1994; Lange, 1996; Matney, Bakken & Huff, 2003). Ontology languages supported by suites of software tools have been developed within the context of terminologies with broad coverage of the healthcare domain (Campbell et al., 1998). Applicability of these tools to the nursing domain has been demonstrated (Hardiker & Rector, 1998; Zingo, 1997). A major remaining challenge is the development of content. However, there is significant progress in that area as well; existing standardized nursing terminologies have shown themselves to be an excellent source.

A number of efforts within nursing (e.g., ICNP) and the larger healthcare arena (e.g., SNOMED CT) are aimed toward the achievement of advanced terminology systems that support semantic interoperability across healthcare information systems. In addition, other research has focused on examining how terminology models and advanced terminology systems relate to other types of models that support semantic interoperability, such as a domain model for nursing, the Health Level 7 Reference

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Information Model (RIM) (Goossen, Ozbolt, Coenen, Park, Mead, Ehnfors & Marin, 2004), openEHR Archetypes (Beale, 2003), Detailed Clinical Models (Goossen, 2008), and an ontology for document naming (Hyun, Shapiro, Melton, Schlegel, Stetson, Johnson & Bakken, 2009). Such interoperability is a prerequisite to meeting the information demands of today's complex healthcare and health management environment.

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List of tables and figures

Table 17.1 Evaluation Criteria Related to Concept-Oriented Approaches

Table 17.2 Possible Representations of the Nursing Activity Concept “Bladder Irrigation”, Using Generic Description Logic Representation and Modified KRSS

Figure 17.1

The semiotic triangle depicts the relationships among objects in the perceivable or conceivable world (referent), thoughts about things in the world, and the labels (symbols or terms) used to represent thoughts about things in the world.

Figure 17.2

A simple graphical example of a formal representation of the nursing activity concept “Bladder Irrigation.”

Figure 17.3

Reference terminology model for nursing diagnoses.

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Figure 17.4

Reference terminology model for nursing actions.

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Figure 17.5

An illustration of a potential mapping using an advanced terminology system between nursing activity concepts from two existing terminology systems.