Perspective

The case for expressing nursing theories using ontologies

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ABSTRACT

Nursing and informatics share a common strength in their use of structured representations of domains, specifically the underlying notion of ‘things’ (ie, concepts, constructs, or named entities) and the relationships among those things. Accurate representation of nursing knowledge in machine-interpretable formats is a necessary next step for leveraging contemporary technologies. Expressing validated nursing theories in ontologies, and in particular formal ontologies, would serve not only nursing, but also investigators from other domains, clinical information system developers, and the users of advanced technologies such as artificial intelligence that seek to learn from the real-world data and evidence generated by nurses and others. Such efforts will enable sharing knowledge and conceptualizations about phenomena across the domains of nursing and generating, testing, revising, and providing theoretically-based perspectives when leveraging contemporary technologies. Nursing is well situated for this work, leveraging intentional and focused collaborations among nurse informaticists, scientists, and theorists.

Key words: nursing theory, ontologies, terminology systems, semantics, artificial intelligence

The fields of nursing and informatics share a common commitment to the use of structured and standards-based representations of knowledge within technical systems. At the most basic level, such structured representations specify ‘things’ that are variously referred to as concepts and/or entities, and the relationships among those things. Nursing theories are an example of organized knowledge within specified domains of nursing. Nurse scholars, like scholars in many disciplines, have a long history of developing theory to guide both research and practice. 1–6 While nursing theories range from abstract to concrete—including grand theories, middle-range theories, and practice theories, respectively—all theories are concerned with sets of concepts or entities, and relationships between and among those things. Scientifically tested theories, and accompanying theoretical frameworks and models that may further explicate the theory, serve to define the structure and phenomena of concern; describe, explain, predict, and/or control outcomes within the domain-specific focus of the theory; and have long been recognized as central to understanding and communicating the knowledge to which the field is committed. Yet, there are concerns that the profession of nursing is at a crossroads related to the future of nursing knowledge as expressed in theory. 7 Among the specific challenges facing nursing, is developing effective and strategic uses of technology for updating and generating new knowledge, and theory at all levels.

Fifteen years ago, Brennan argued, “As the field of biomedical informatics matures, investigators and systems implementers increasingly rely on theories, models, and frameworks to guide their work. Of these 3, theory provides the greatest value to any discipline, because theory provides well-validated pathways to link observed phenomena with foundational knowledge, thus enhancing efficiency and generalizability.” 8

Towards these ends, multiple stakeholders recognize the role of theory in relationship to informatics. For example, the American Medical Informatics Association (AMIA) calls out the development, study, and application of theory as essential to biomedical informatics, particularly in the areas of generating, storing, retrieving, using, and sharing biomedical data, information, and knowledge (D-I-K). 9 Additionally, the most recent Nursing Informatics Scope and Standards of Practice, published by the American Nurses Association (ANA), emphasizes the role of D-I-K and wisdom (D-I-K-W) as a metaparadigm of nursing informatics, along with the metaparadigm of person, environment, health, and nursing. 10 But how—and why do we express nursing theories, theoretical frameworks, and theoretical models in ways that leverage and exploit the potential of contemporary technologies?

Ontologies are a technical approach for expressing knowledge as sets of “things” and the relationships between things for use within connected computing environments. 11 While the field of computer science defines ontologies as “a set of logical axioms designed to account for the intended meaning of a vocabulary”, 12 the word “ontology” is also applied to a spectrum of terminology systems, including glossaries,

Received: 6 March 2023. Revised: 17 May 2023. Editorial Decision: 20 May 2023. Accepted: 5 June 2023

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One of the differentiating features among such terminology systems is the manner by which things and their relationships are expressed, for example, as relational models, database schema, XML, or—in the case of formal ontologies—logical axioms.

The use of ontologies for computable knowledge representation is a familiar notion in AI. In contrast to humans who can often innately reason about and understand how things fit together without highly structured definitions or explicitly stated relationships, machines require explicit expressions of things and relationships. Formal ontologies provide strong semantics, enabling AI-based inferencing of concepts and relationships across heterogeneous databases, the extraction of data and information from a range or repositories, and the linkage of data within a web environment.

Expressing nursing generated concepts and relationships in computable formats has been a focus within the nursing informatics and health care standards communities for nearly 2 decades. For example, although typically atheoretical, there are notable examples of nursing informatics-led initiatives that have successfully expressed nursing classification systems within existing formal ontologies.14–18 Building on that early work, others have applied standards-based approaches that bridge the data-information boundary by demonstrating the “binding” of concepts from ontologies to the information models used to enable semantic interoperability when messaging across information systems or applying decision support systems to individuals’ data.19,20 Some of those initiatives, such as the expression of risk for pressure injury and its prevention and treatment, are examples of expressing implicit practice-level theories, and executing that theory on semantically harmonized, standards-based data. Examples of leveraging middle-range theory with tightly coupled terminology are also evident. For example, the Omaha System, described as a middle-range theory for nursing, is expressed as a multi-axial terminology system that underlies documentation systems and repositories of those data. The theory and terminology based documentation system, and databases, were designed in full awareness of each component.21 By analyzing datasets through both theoretical and terminological lenses, researchers applying the Omaha System have identify new relationships between “things.”22 While few theories in nursing have that sort of integration into the documentation systems and practice, this and other studies using the Omaha System demonstrate the strength of applying comparable and consistent expressions of concepts and relationships within a theory. It is of note that currently, there is overall a lack of integrated nursing domain knowledge and theories evident in the context of ML applications generally, and other techniques such as deep learning or “black box” AI.24

Calls for expressing theories as formal ontologies are also evident in the non-nursing literature. A recent panel convened by the National Academy of Sciences noted the benefits of using formal ontology development as a tool to sort through overlapping concepts across theories, and the potential to clarify, test, and refine theories when those theories are expressed as ontologies that are logically sound, accurately reflect the domain, and perceived as usable by scientists, practitioners, and other stakeholders.25 By incorporating domain knowledge into technological applications, we are able to tell the machine what we know and the machine can therefore inform us of what it found. In this way, formal ontologies, as a way to tell the machine what we know, have been a key contributor to high-performant ML models.26 Formal ontologies could inform machine-interpretable, theoretically based “paths” among encoded data elements.27

Methods for theory development, evaluation, revision, and application are clearly going to change in the context of vast data stores, an emphasis on real-world data and information, and the rapid uptake of AI-based technologies. Importantly, there are ongoing calls for useful theory that is explainable, generalizable, and testable by humans.28 The hypothesis generating findings from atheoretical AI and ML are likely to be extremely useful in advancing the development of specific or new theories in nursing, but ontologies that can express theories are needed to evaluate and refine theories based on large scale heterogeneous data resources.

We are not suggesting that all nursing theories should be or can be expressed as formal ontologies; less expressive terminology systems such as those mentioned earlier under the broad umbrella of ontologies will be needed.

The key points are that ontologies need to “recognize” theory, and that expressing theories using ontology-based approaches requires careful consideration of how or if that theory can be expressed within the constraints of the “type” of ontology. Of particular importance is the need to be selective about the evidence base underlying theories; we have the potential to do harm if we build systems that act on hypothetical, inferred relationships and propositions that are not supported by evidence. Rigorous testing of any efforts to express theories in ontology formats will require, at a minimum, careful consideration of any candidate theory including the extent to which propositions can be made explicit; the identification and mapping of concepts and/or entities, and relationships, to existing terminology systems so that redundant representations are avoided; evaluations of the targeted ontologies to identify representational constraints imposed by the ontology; and the development of use cases against which any implementation can be evaluated.

Nursing as a discipline is ideally situated to launch intentional and focused collaborations among nursing informaticists, scientists, theorists, and practitioners to express components of theories in ontologies. Nurse informaticists can lay an essential foundation needed to express the structure of nursing knowledge as reflected in validated theory, and in the context of amassed data, information, and ever-expanding technologies. As a nursing informatics community, we have learned how to express nursing-generated data, information, and knowledge in formal ontologies. We can build on and extend those methods. Furthermore, many nurse informaticists have been engaged in complex, multidisciplinary teams and have experience navigating complex socio-technical environments and computational tools to build ontologies within contexts that are not nursing-specific. We can expand on that experience to contribute to theory development and use. As a nursing community broadly, theory is embedded into all levels of nursing education and scientific preparation; thinking about relationships between concepts is “in the water.” We have a tremendous opportunity and perhaps, as noted by Roy, an obligation to respond to needs for advancing theory, and making well-validated theory available to serve as pathways linking “observed phenomena of the domain with foundational knowledge.” 8

Collectively, we can express components of theories in various types of terminology systems. There will be challenges...
along the way, and dedicated effort will be required. However such an initiative would serve not only nursing, but also investigators from other domains, clinical information system developers, users of advanced technologies that seek to learn from the real-world data and evidence generated by nurses, and ultimately the people and communities who benefit from nursing knowledge applied to health and healthcare.

**FUNDING**

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**AUTHOR CONTRIBUTIONS**

Conception and design: EU, PAB, and MRH. Drafting of Manuscript: EU, PAB, and MRH. Final review of the submission and agreement to be accountable for all aspects of the work: EU, PAB, and MRH.

**CONFLICT OF INTEREST STATEMENT**

None declared.

**DATA AVAILABILITY**

No data were generated or analyzed in support of this manuscript.

**REFERENCES**