# The Evolution of Data-Information-Knowledge-Wisdom in Nursing Informatics

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The data-information-knowledge-wisdom (DIKW) model has been widely adopted in nursing informatics. In this article, we examine the evolution of DIKW in nursing informatics while incorporating critiques from other disciplines. This includes examination of assumptions of linearity and hierarchy and an exploration of the implicit philosophical grounding of the model. Two guiding questions are considered: (1) Does DIKW serve clinical information systems, nurses, or both? and (2) What level of theory does DIKW occupy? The DIKW model has been valuable in advancing the independent field of nursing informatics. We offer that if the model is to continue to move forward, its role and functions must be explicitly addressed. **Key words:** *information science*, *nursing informatics*, *nursing philosophy*, *nursing theory*

*If we cannot name it, we cannot control it, finance it, teach it, research it, or put it into public policy.*

Norma Lang (in Clark and Lang)[1]

**M**AKING NURSING WORK VISIBLE has been a historical challenge that the profession continues to contend with. Early research sought to distinguish nursing work as distinct from other professions, informed by its own bodies of knowledge. Meanwhile, contemporary challenges include developing quantifiable ways of representing nursing work, developing methods to capture aspects of nursing that "can't be quantified," identifying nursing-sensitive outcomes, and issues related to the move toward digitized health systems. Operationalizing ways of making nursing work visible, valued, and "counted" in health systems, facilitated by the use of information technology has been a foundational driving force in the field of nursing informatics.[1]

Seminal work by Graves and Corcoran[2] was aimed to outline the scope and define the field of nursing informatics and to delineate and define nursing work as related to information technology. A foundational conceptual approach described by Graves and Corcoran as central to nursing informatics is the *data, information, knowledge, wisdom* (DIKW) framework, which continues to play a central role in the field today. By outlining the definitions, roles, and interrelationships within DIKW, the framework has undoubtedly been instrumental in moving and informing the field toward the goal of making nursing work visible. Interest in DIKW has been sustained, and its evolution has continued over the decades, illustrated by the various iterations and revisions of the model to meet the needs of contemporary nursing[3-5] and the continued efforts and approaches to better understand the framework and explore its application.[6]

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The aims of this article are (1) to examine the theoretical foundations of the DIKW model through deconstruction of some implicit claims within the model and (2) to step back to examine potential reasons why DIKW has come to be depicted in the way that it has. To achieve our aims, we have used 2 approaches. First, we conducted a literature review, focusing in particular on other fields of study where DIKW has been taken up. Second, we examined syntheses of some main critiques of DIKW, particularly in relation to the way that DIKW has been taken up in nursing. This second approach led to a philosophical exploration of the implicit assumptions that the concepts within DIKW are founded on and interpretations of the model's presumed purpose and theoretical application. Our philosophical exploration includes some reflections on the implications for nursing's obligations to diverse populations and interdisciplinarity.

## DIKW IN NURSING INFORMATICS

Graves and Corcoran's[2] seminal paper, "The Study of Nursing Informatics," established nursing informatics as a field of scholarly inquiry in the late 1980s and early 1990s.[6] They describe nursing informatics as "a combination of computer science, information science and nursing science designed to assist in the management and processing of nursing *data*, *information* and *knowledge* to support the practice of nursing and the delivery of nursing care."[2(p227)] Nursing informatics captures the juncture of these 3 core sciences; the focus on nursing science differentiates nursing informatics from other specialties, such as biomedical informatics.[5] Graves and Corcoran's article is acknowledged as instrumental in shifting the discourse in nursing informatics from being concerned with technology itself to the *purpose* of technology and concepts related to information science in the context of nursing.[7] On the foundations of nursing informatics, Graves and Corcoran explained:

This framework for nursing informatics relies on a taxonomy and definition of the central concepts of *data*, *information* and *knowledge* put forward by Blum (1986), who defines *data* as discrete entities that are described objectively without interpretation, *information* as *data* that are interpreted, organized or structured and *knowledge* as *information* that has been synthesized so that interrelationships are identified and formalized.[2] (See Figure 1 for Graves and Corcoran's depiction of data-information-knowledge [DIK].)

In the field of nursing informatics, Nelson and Joos are cited as the first to add the concept of *wisdom* in 1989, described as the "appropriate use of knowledge in managing or solving human problems . . . it [wisdom] is knowing when and how to use knowledge to manage a patient need or problem."[8] The American Nurses Association's Scope and Standards for Nursing Informatics adopted the inclusion of wisdom to the DIK framework in 2008, arguing that it "reflects today's emerging mandate for evidence-based practice and decision support resources for the knowledge worker."[9(p855)]

The conceptualization of DIK and the addition of *wisdom* are important developments in the attempts to better articulate and make nursing work visible, particularly in relation to the digitization of health systems. DIKW has been instrumental in expanding the scope of practice in nursing informatics to be "no longer fully defined by the functionality of a computer and the types of applications processed by a computer . . . [but is] now defined by the goals of nursing and nurse-computer interactions in achieving these goals."[4(p27)] Through these
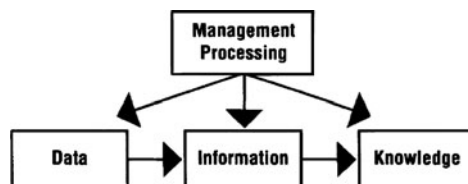


**Figure 1**. Conceptual framework for the study of nursing informatics (as proposed by Graves and Corcoran[2]). Reprinted with permission.

developments, DIKW has become a canonical framework in nursing informatics.

## ORIGINS OF DIK AND DIKW

Graves and Corcoran adopted the DIK framework from Blum's 1986 book, where he suggested that medical computing had 4 phases: (1) 1955-1965: experimentation and orientation; (2) 1965-1975: data processing success; (3) 1975-1985: information processing success; and (4) 1985-[1986 and future]: knowledge processing success. He further described 3 types of applications: (1) data-oriented applications, such as systems designed for business data, clinical laboratory data, patient monitoring, diagnostic systems, and imaging (eg, computed tomographic scan); (2) information-oriented applications including clinical information systems that can provide administrative support (eg, reduce errors) and medical decision support (eg, alerts and reminders to support clinical decision making); and (3) knowledge-oriented applications such as bibliographic databases, and artificial intelligence systems (ie, systems that have the ability to apply "smart reasoning").[10] In his book, Blum acknowledges that systems at the time had difficulty codifying "the most elementary body of knowledge—common sense." It is unclear where the model posed by Blum originated. Desrosières[11] suggests that the origins of DIK derives from the 17th-century ideas of taxonomies of nature that later matured into classification of populations toward "the construction and stabilization of social order . . . , the production of a common language allowing individual acts to be coordinated and . . . [for systems to be able to be] capable of orientation and triggering action." Given the rapidly increasing proliferation of complex work related to nursing informatics happening nationally and internationally, we believe that an approach such as DIK can provide a common language and coordination of individuals from various disciplines (eg, nursing, computer science, information science, medicine) is most welcome.

The addition of "wisdom" to the DIK model has largely been attributed to Ackoff's 1989 address to the Society for General Systems. In this address, Ackoff[12] accentuates the interplay between knowledge and wisdom, and although he does not present a graphical depiction of the ideas, he clearly suggests a hierarchical format wherein the concepts of DIKW build one upon the other.

## THE EVOLUTION OF DIKW IN NURSING INFORMATICS

Since it was first introduced in nursing 26 years ago, the evolution and refinement of DIK and then DIKW have been ongoing, with the most recent changes to the model made in 2013.[4] The various revisions of DIKW have aimed to address the limitations of the original model by providing further details of the relationships and interactions between the concepts of *DIKW*. Figures 2-4 show the evolution of visual depiction of the DIKW model.

The relevance of the DIKW framework in nursing informatics is illustrated by the ongoing adaptation and extension of the framework to underpin research studies. For example, Gee et al[13] suggest an extension of the DIKW framework by integrating clinicians and the e-patient into the model. This is framed as the *DIKW Collaborative Model*, where the e-patient, or electronic patient, is one who uses information resources on the Internet to self-manage his or her own health. Gee et al[13] posit that the crucial interaction between the clinician and the e-patient can be supported by the DIKW framework and suggest that data could be coproduced by patients and clinicians. They note that the "e-patient could educate the health care team on what data mean in their life context . . . and together they would create plans . . . using collective wisdom from support groups, social networking sites, blogs, databases and research"[13] (see Figure 5).
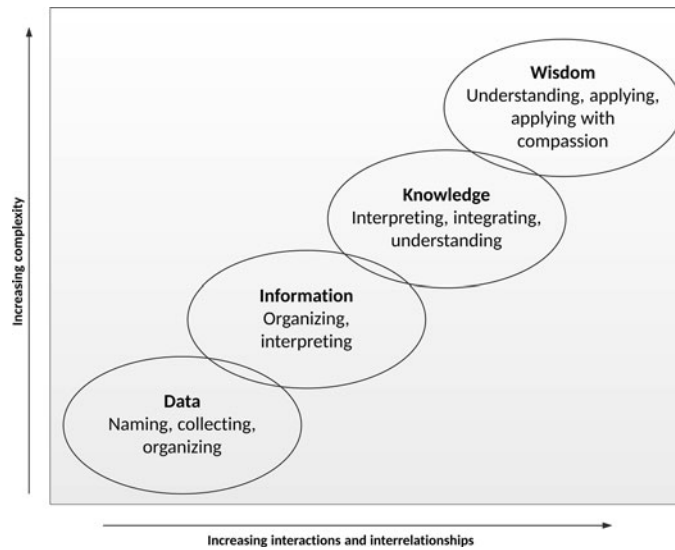
**Figure 2**. Nelson DIKW, version 1 (2001), is the original visual depiction of the DIKW theoretical model as referred to in nursing informatics. DIKW indicates data-information-knowledge-wisdom. Copyright ownership by Ramona Nelson, Ramona Nelson Consulting. All rights reserved. Reprinted with permission.



**Figure 3**. Nelson DIKW, version 2 (2008), adds constant flux, suggesting the possibility of bidirectional movement across the DIKW continuum. DIKW indicates data-information-knowledge-wisdom. Copyright ownership by Ramona Nelson, Ramona Nelson Consulting. All rights reserved. Reprinted with permission.
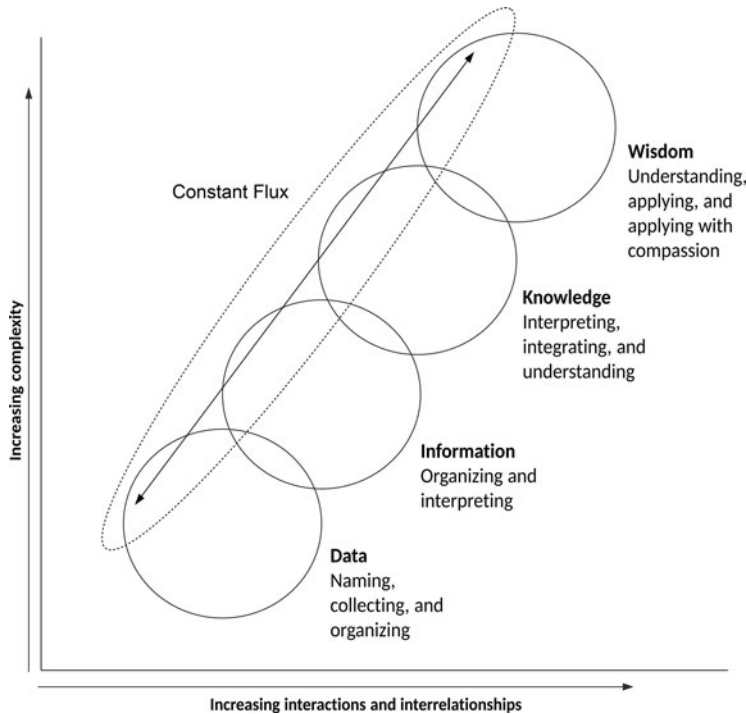
**Figure 4**. Nelson DIKW, version 3 (2013), maintains bidirectional movement with constant flux and is revised to suggest greater interaction, overlap, and interrelationships between concepts, as well as the possibility of moving back and forth between constituent concepts. DIKW indicates data-information-knowledge-wisdom. Copyright ownership by Ramona Nelson, Ramona Nelson Consulting. All rights reserved. Reprinted with permission.
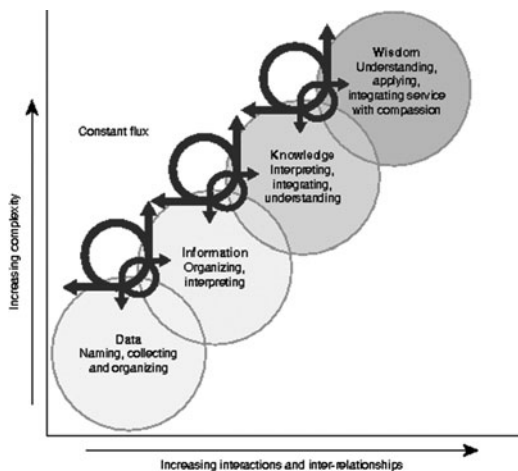
Looman et al[14] used the DIKW framework to inform their study of care coordination in the context of telehealth for families. In their conceptual model, the DIKW constructs are depicted as underpinning a model of care coordination; data are conceptualized as historic or current and as subjective or objective, and
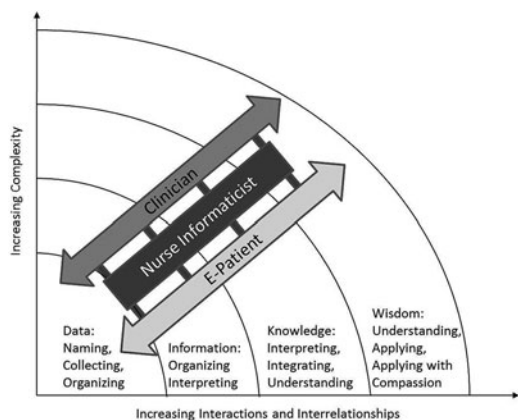


**Figure 5**. The DIKW model as depicted by Gee et al.[13] DIKW indicates data-information-knowledge-wisdom. Reprinted with permission.

knowledge is conceptualized as tacit or explicit, and these are underpinned by wisdom (see Figure 7).

Most recently, Matney and colleagues[15,16] have proposed a theory of *Wisdom-in-Action.* In this model, the concept of data has been subsumed into the context of electronic health records and the concepts of information, knowledge, and wisdom are clearly delineated as interacting with each other (see Matney[15] for visual representation).

## CRITICISMS OF THE DIKW MODEL

Although various revisions of DIKW in nursing informatics illustrate continued attempts at better delineating and understanding the model and its application, critiques of DIKW in other fields have been more explicit, systematic, and nuanced and have sought to challenge the model. The following sections consider perspectives of DIKW from nursing informatics in light of criticisms of DIKW from the fields of information science, knowledge management, geography, management information systems, and library information sciences. The critiques we have synthesized from our literature review focus on the limitations of DIKW's hierarchical structure and epistemological narrowness in understanding the concepts of DIKW.

## LINEARITY AND HIERARCHY IN DIKW

Published critiques of DIKW outside of nursing focus largely around the uncritical acceptance of DIKW and the implications of accepting it at face value, as well as the inability to operationalize the model.[17-21] As we show in what follows, these critiques coalesce around concerns about the linearity and hierarchy implicit in how the model is taken up.

In the field of information science, DIKW is referred to as the *knowledge/information hierarchy* or *information/knowledge pyramid* and is visually represented in a manner
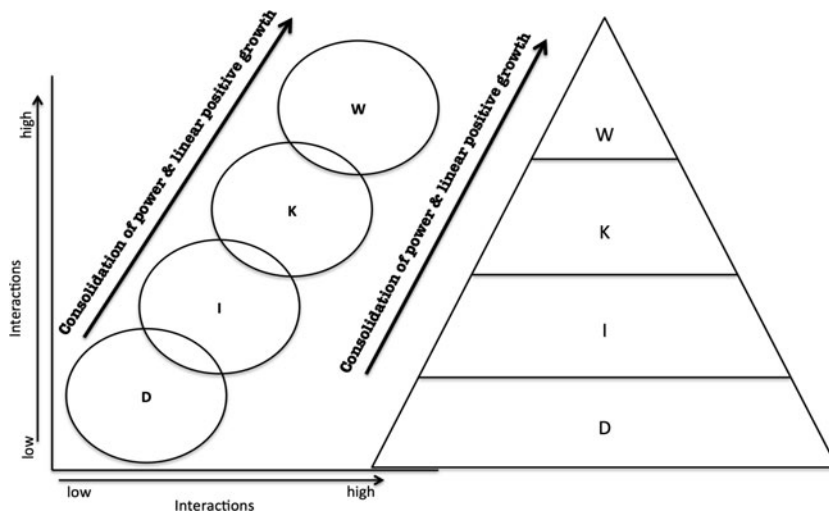
**Figure 6**. A side-by-side comparisons of the DIKW models as depicted in nursing informatics (left) and computer science, management information systems, and library sciences (right) illustrate the common attributes of DIKW visualizations: consolidation of power, linear and positive growth, and an implicit assignment of value to concepts (ie, "building" toward to the pinnacle of wisdom, which is the most important). DIKW indicates data-information-knowledge-wisdom.

different from that of DIKW in nursing informatics (see Figure 6). Data are described to be most abundant, forming the foundational level upon which the remaining concepts build on, with the decreasing width of the triangle at each level suggesting decreased abundance.[22] Concurrently, movement up the triangle suggests increasing power to support the ability to take appropriate action.[22]

In information science, reference to DIKW as a knowledge *hierarchy* alludes to the assignment of value to concepts in the model. Specifically, concepts are characterized by dominance or importance.[22] Depicting DIKW as a pyramid is suggested as a means of proposing a consolidation of power in the upper levels from the lower levels.[20,22] In nursing informatics, DIKW is not visualized in the same way. However, a side-by-side comparison of visualizations illustrates similar features of the models (see Figure 6). Notably, the visualization of DIKW in nursing informatics depicts a similar allusion to linear and "positive" growth, a hierarchy among concepts, and a consolidation of effect in the movement from data to wisdom.

In the field of geography, Poore and Chrisman outline the problematic nature of this depiction of DIKW, asserting that "the information pyramid embodies and normalizes theories of power, reflecting the hierarchical social structures of the old industrial economy."[23(p511)] They suggest that the valuing of concepts in DIKW has the potential to spill over and unintentionally be seen to apply to individuals and professions, "with manual workers on the bottom and knowledge workers and bosses on the top."[23(p511)] Furthermore, depicting *knowledge* and *wisdom* as higher up in the traditional nursing informatics depiction of DIKW suggests that they are more valuable than *data* and *information.*

Indeed, a premise of DIKW is the movement toward wisdom as the ultimate goal. Frické suggests that this depiction of DIKW is reminiscent of "inductivist growth-by-accretion model of science" that has largely been abandoned—thanks to the work of Popper and Kuhn demonstrating the fallible and value-laden nature of knowledge—in favor of accepting that "even the most cherished of 'pure observational facts' is open to the possibility of revision."[18(p6)]
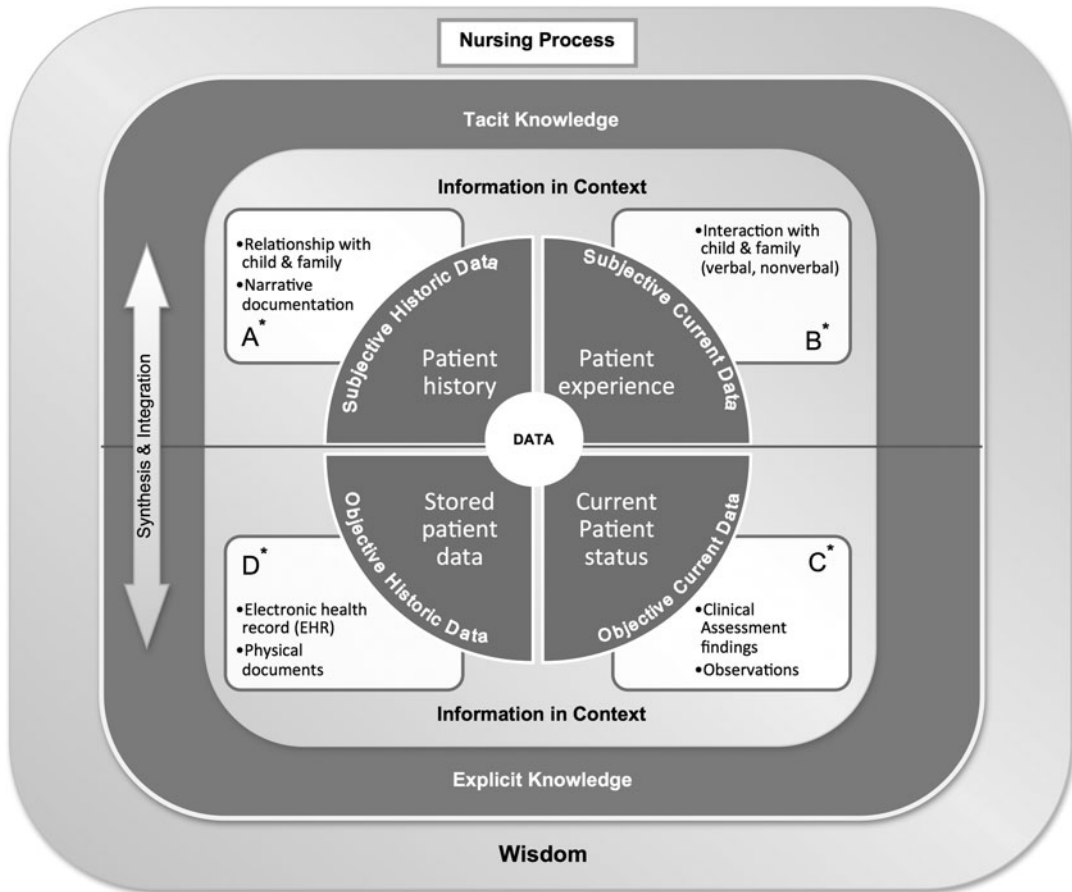
**Figure 7**. The DIKW model as depicted by Looman et al.[14] DIKW indicates data-information-knowledge-wisdom. Reprinted with permission.

The notion of data eventually consolidating into wisdom is problematic in a number of ways. For one, it reflects outdated ideals related to how science develops, as mentioned previously. Second, the question arises of just how the movement from data to wisdom takes place—what causes the movement? Is there an innate inertia that moves, consolidates, and transforms data across the other DIKW concepts to reach the pinnacle of wisdom? In the field of medical informatics, Georgiou critiqued the underlying assumptions of the *informatics model*, stating that

"It [the informatics model] is . . . founded on some questionable assumptions, particularly if the process of data/information/knowledge is viewed linearly, whereby the mere capture of data on one side of the spectrum can lead seamlessly to information and then knowledge. In reality there are a number of interrelated activities involved in the generation of information.[24(p128)]

Although these criticisms draw from the pyramid structure, the similar hierarchical structure alluded to in the nursing informatics model of DIKW warrants concurrent consideration of this criticism.

Another salient critique of DIKW relates to the linear movement between concepts within the model. These are, arguably, shaped by the values attributed to each of the concepts of *DIKW*. The depiction of DIKW suggesting linear, unidirectional

movement between concepts has been challenged. Various authors have highlighted the lack of consensus and varying views on how DIK is defined, bounded, and created, positing instead the possibility for bidirectional movement between concepts as necessary.[17,25,26]

Indeed, this criticism of linearity is among the first addressed in the evolving iterations of DIKW in nursing informatics, resulting in revisions to the model to indicate the possibility of bidirectional movement across *DIKW* (see Figure 3), which we elaborate on further later in this article. Nevertheless, problematic aspects of DIKW related to linearity and hierarchy remain. Gee et al[13] attempt to manage this issue by allowing for movement back and forth; however, the Gee et al model retains a sequential format and does not allow for the possibility of relationships between concepts not adjacent to each other, for instance, between wisdom and data. The model presupposes that each component must "go through" the other to move to the next step. However, in what follows, we explore how this sequencing may not necessarily be required.

Related to the restrictions of linear movement in depictions of DIKW, a further point of criticism addresses an implicit restriction of movement within the model—specifically, the suggestion that all movement must begin from data, understood to be the building blocks underpinning the model. Various authors have argued that this view is problematic in that it neglects to take into account contextual factors that influence where the beginning point on the DIKW continuum is and in which direction movement should flow. For instance, Tuomi[26] suggests that the direction of movement between concepts in DIKW will vary depending on whether the user is a knowledge seeker or knowledge creator. Knowledge seekers *place data into context to create information* and make these actionable in knowledge, much in line with "traditional" descriptions of DIKW.[26] However, Tuomi[26] also highlights that behavior and movement through DIKW differ for knowledge creators who *begin with knowledge to create information*, which are then needed to create data. Similarly, it is suggested that knowledge and information must exist as prerequisites to create the specific contexts, structures, and semantics that facilitate creation of data.[26] Tuomi[26] goes even further to support the argument that data are more important than knowledge, proposing an inversion of the DIKW hierarchy with data placed at the top.

The valuing of knowledge as something either to be mobilized or to be created is argued as a means to shape "how we know what we know" and to understand what kinds of knowledge are possible.[27] In addition, the diversity in definitions and conceptualizations of hierarchy in DIKW suggests that *values* play an important role in determining directionality in DIKW. There is arguably an inextricable connection between epistemology—the nature of knowledge—and axiology—the ways that values are attributed, in shaping perceptions of knowledge creation and utilization.[26,28,29]

Some critiques of DIKW in the broader literature have been similarly recognized in nursing informatics by the ongoing refinement of representations of DIKW. For instance, various iterations modified the initial DIKW model in nursing, with later versions of the model incorporating bidirectional movement between concepts, referred to as "constant flux," indicated by double-ended arrows that span the concepts of *DIKW*.[5] The most recent modification of DIKW by Nelson goes even further in attempt to clearly depict the potential for bidirectional movement between adjacent concepts in DIKW. The notion of "constant flux" is revised: rather than having 1 bidirectional arrow spanning the model, the authors instead include 2 bidirectional arrows between adjacent concepts. This latest revision of the model suggests the possibility of overlapping and interrelated movement between concepts, and the possibility for treating data as information, and vice versa, depending on context.[4] For example, Nelson and Staggers[4] suggests that a novice

may view a patient's laboratory result as data whereas an expert may view that result in the context of the patients' overall status, and the expert's interpretation of the data point as information may cause the expert to alter the patient's plan of care. The Looman et al[14] adaptation of the DIKW framework addresses the problem of linearity by depicting DIKW as underpinning a model of care coordination. In their article, they do not explicitly state that they are attempting to manage the linearity problem; however, their adaptation implies that the hierarchical model was of limited usefulness for operationalization in a research study.

Overall, the critiques and adaptations in nursing informatics we have sketched out earlier indicate the continued relevance of DIKW and, arguably, illustrate the continued evolution required to address the challenges and limitations in understanding and using the model. To further contribute to understanding DIKW and its utility in nursing informatics, however, the issues related to the assignment of values to DIKW concepts and the potential of beginning in a place other than *data*, and the implications arguably, should be addressed.

## IMPLICIT PHILOSOPHICAL GROUNDING OF CONCEPTS IN DIKW

In addition to critiques of the linear and hierarchical nature of DIKW, the implicit philosophical groundings of DIKW are arguably another problematic feature of the model. In particular, numerous critiques in the field of information science have pointed to the strict and narrow definitions of the concept of *data* and its seeming incommensurability with the realities of *data* in practice or application—namely, data as not always easily clearly defined or distinguished from information and knowledge.[18,30] In the DIKW model, data are viewed as the most basic and fundamental building blocks of knowledge, information, and wisdom. In addition to pointing to *data* as the basic component from which all the other concepts build on, primacy is also being given to a very specific view of *data*.

The logical flow in DIKW suggests that all *knowledge* and *wisdom* ultimately stem from objective, value-free, and "pure" *data*.[2,6,18] However, a growing number of critiques have highlighted the limitations of this view and have argued for the impossibility of data existing without context, or being generated without prior knowledge.[18,26] Recently, growing interest in Data Science and Big Data has recast the role of *data*. Briefly, Big Data refer to massive data sets composed of enormous amounts of data, now being routinely collected as a result of the ubiquity of computing. Data Science centers on the development of innovative computational techniques to analyze these massive data sets that include data harnessed via the Web (eg, Google search queries and Facebook behavior patterns, electronic health record repositories, insurance claims, consumer reports, and mobile phone usage patterns).[31,32] Big Data analytics are already being used as a powerful decision-making tool—it is through Big Data, for example, that Google can predict influenza outbreaks and unemployment trends prior to release of official statistics, based on the search terms and timing and location of search queries.[33] Returning to the role of *data*, Kitchin[34] suggests that specific perspectives and contexts, disciplinary or otherwise, determine how *data* are conceptualized and used. Whereas to a physicist, data may be simply composed of zeroes and ones and innately meaningless until patterns are formed,[34] to a nurse, data may be less discrete and require contextualization (eg, determining which physiological data are relevant when observing for impending shock).

Building on these critiques, it can be argued that these assumptions of the role and nature of data are contingent upon the observer's particular ontological, epistemological, and axiological stance. Briefly, ontology is used here in the philosophical sense, referring to the nature of existence and asks the question "what exists?" or "what is?"[27] and axiology refers to the theory of values,

includes ethics (what is "right" and "good"; "what ought to be") and aesthetics (beauty and harmony).[35,36] To expand, consider the following scenario. Two people, person A and person B, are presented with the question: "What is the most basic unit of *knowledge*?" Person "A" may lean toward a modified realist ontology in his or her view of DIKW. Modified realism accepts the existence of an objective "real world" that exists independently of human thought and knowledge but accepts that knowledge of this world is fallible.[37] Accompanying person A's realist ontology is an objectivist and social constructionist epistemology. In other words, the acceptance of a meaningful objective reality (objectivism) accompanied by a simultaneous acknowledgment that knowledge, meaning-making, and representations of the "real world" are socially constructed (social constructionism).[27,37] That is, history, culture, and social phenomena contribute to how the "real world" is described and understood. In terms of values (axiology), person A may place primacy on accurately measuring observations and get as "close" to the "real world" as possible while acknowledging the importance of recognizing the significance of context. Therefore, when turning to the question of the basic unit of *knowledge*, person A would likely agree with current descriptions of DIKW wherein *data* are treated as the most fundamental unit, as they represent measurements and observations that get as close to the "real world" as our senses and instruments (ie, extensions of sensory information) can allow. However, person A would also acknowledge that taking up *data* as pure "fact" is erroneous, as "fact" is also influenced by the contexts that shape the larger phenomenon being addressed.

In contrast, suppose that person B leans toward a more *relativist* ontology in viewing DIKW. This ontological stance rejects the notion of "truth" or a "real world" and suggests that there is no objective meaning in the world.[27] Person B also holds a constructivist epistemology, which posits that meaning only arises when humans interact with the world

and ascribe meaning to things. Furthermore, meaning-making is deemed to be shaped by unique experiences of individuals, recognizing that individuals inhabit different worlds.[27] Accompanying these ontological and epistemological stances is the axiological valuing of individual experience and understanding, as instrumental in creating knowledge. Posed with the same question of what comprises the most basic unit knowledge, person B would likely reject the definition of *data* as defined by DIKW, as there are no universal truths. Instead, *data* would be widely varied and not be condensed simplistically into categories. Indeed, the notion that individual experience and meaning-making is reducible to measurable *data* would be problematic in and of itself. Person B may altogether reject the idea that the DIKW model affords room for individual meaning-making, given that it is based upon a strict definition of *data*.

These opposing scenarios presented earlier, although simplified, illustrate how specific ontological, epistemological, and axiological stances taken by individuals ultimately shape how the hierarchy that is implicit in the DIKW model might be interpreted. Furthermore, a key point to highlight here is that it is not "good" or "bad" that data are treated as value-free or contextualized but rather the importance is in being cognizant of the conceptualizations of data being used, as these conceptualizations ultimately influence further ways of producing and using these data.

Taking this philosophical stance in understanding the implications of assumptions in DIKW is particularly salient in nursing work, where a plurality of perspectives and approaches to developing and using knowledge for patient care exist.[28] Indeed, the importance of being cognizant of these implicit assumptions is further highlighted upon returning to Graves and Corcoran's article. Recognizing the limitations of technology to process only empirical knowledge at the time, the authors pointed to the need to explore ways of incorporating, managing, and supporting Carper's[38,39] 4 ways of "knowing" (empirical, ethical, personal, and aesthetic) in the study

of nursing informatics, as the latter 3 are less discrete and cannot be easily processed.

In one of the few articles that take a philosophical approach to examining the DIKW model, Matney and colleagues[6] proposed that the epistemological basis for understanding the model can be understood collectively through postpositivism (belief of a "real" world while acknowledging "the social aspects of reality") and Gadamerian hermeneutics (interpretation with focus on "the centrality of language and dialogue to understanding"). The author suggests that *data* and *information* can be understood through a postpositivist epistemology whereas *knowledge* and *wisdom* can be understood through hermeneutics.[6] However, a question this brings forward is how a model comprising concepts whose foundations differ ontologically—namely, objectivism (*data* and *information*) and something closer to relativism (*knowledge* and *wisdom)*—can be understood to be cohesive? In particular, how can such a composite model be made commensurable, given the linear logic argument made in DIKW visualizations that each concept builds on the other (ie, *data* become *information*, which becomes *knowledge*, which becomes *wisdom*)?

## WHAT OR WHO IS DIKW MEANT TO SERVE?

To address the aforementioned question, we look to literature in nursing informatics that delineates the nurse as playing an inextricable role in DIKW.[2,3,5,6] Descriptions of DIKW often refer to a prominent role of the nurse who incorporates additional information and knowledge such as clinical experience, tacit knowledge, and intuition and also draws from *data* and *information* to arrive at the more complex *knowledge* and *wisdom* components of the model. To better understand the relationship and potential dynamics between nurses and computerized clinical information systems as related to DIKW, we argue that an important clarification in con-sidering using or applying DIKW is related to what or who the model is meant to serve.

Without clear delineation of who or what the DIKW model is meant to serve, it is difficult to determine which concepts are meant to refer to functions of computerized clinical information systems (ie, systems used to manage clinical information required for nursing practice), which concepts refer to functions and actions of nurses (ie, as users interacting with the system), and where they apply to both or overlap. This lack of clarity contributes to the challenges in understanding the applicability of DIKW. Arguably, how *DIKW* is interpreted and taken up can be more clearly understood when situated in a specific context (ie, in information systems or in nursing practice).

## DIKW FOR COMPUTERIZED CLINICAL INFORMATION SYSTEMS

The applicability of DIKW in understanding the use of computerized clinical information systems appears clearer in comparison with its utility in human information processing. Machlup notes, "When we talk about *data* in information science, we basically refer to 'things fed into a computer.'"[40(p647)] Indeed, the appeal of DIKW relates to its fit with the way computers process information. In the context of computerized systems, it is logical and necessary to view *data* as value-free facts that are observable and measurable in order for computerized information systems to function. Furthermore, the propositions that *data* are basic, discrete, "building blocks," processed *data* and addition of context creates *information*, and synthesizing *information* and identifying patterns and relationships create *knowledge* are features that can be programmed into computerized clinical information systems.[3,6] Nelson and Staggers[4] effectively illustrate how DIKW can be used to understand automated systems at different levels of sophistication, from information systems to decision support systems and expert systems. In contrast, the possibility of

developing computerized clinical information systems that include features of the complex concept of *wisdom* remains uncertain. Although various definitions and interpretations of wisdom exist, authors similarly liken wisdom to a state of peak human performance that transcends mere knowledge and information.[19] This suggests that wisdom requires drawing from multiple types of knowledge (with diverse ontological and epistemological foundations, history, experience, and axiology),[4,6,19,20] features that cannot be simplistically programmed into computerized clinical information systems. In fact, it was in questioning the possibility of programming computerized management information systems to demonstrate wisdom that motivated Ackoff's[12] initial introduction of the DIKW hierarchy. While the discussion of efforts to develop intelligent systems (eg, IBM's Watson cognitive system)[41] may eventually demonstrate characteristics of wisdom, such discussion, while beyond scope of this article, may be important for monitoring and tracking future developments in computerized clinical information systems in the context of DIKW.[19]

## DIKW FOR NURSING PRACTICE

In contrast to the relative ease that DIKW can be applied to computerized clinical information systems is the understanding of DIKW as applied to the context of nursing practice and human information processing. Specifically, focusing on the concepts of "value-free" *data*—as the foundation upon which the model stands—and *knowledge*—as issues around nursing's pluralistic epistemologies—is especially important, given that knowledge is portrayed as a precursor to *wisdom*. Nelson and Staggers[4] suggest that humans can be understood as open systems who take in, process, and output concepts of DIKW and point to learning theory as a framework for understanding this process. However, this stance does not address axiology and assumes the separation of human understanding from ascribing value to what counts as *DIKW*. Given

that nursing has an axiological (ethical) mandate to serve diverse—and often vulnerable—populations, being clear about our values-based purpose is crucial.[28]

It is difficult to make the case that human conceptualization and use of *data*—the foundational "bedrock" of the DIKW model—can truly be viewed as discrete, objective, and value-free, as the definition of this concept and the succession toward subsequent levels of the model necessitates. The concern here is similar to a concern articulated by Ma, from library science, who states:

For humans, information and knowledge are not processed data; rather, we learn by being situated within and understanding complex webs of relations of persons, events, social and political structures, and many other things. Further, we seek agreement with each other on what things mean through learned social and cultural tools and categories . . . . The analogy of *data* to human stimuli and machine process output to knowledge is a bizarre analogy that obfuscates rather obvious difference between designed and organic agents.[20(p720)]

The suggestion of understanding humans as open systems that incorporate DIKW is also problematic in that there is an assertion that *data* exist "out there" independent of context, ready to be absorbed and assimilated by human information processing. As argued earlier, what is considered "*data*" cannot be separated from axiology and context and, currently, the limitations as to what can be considered data are particularly significant in nursing. Consider the concept of pain in nursing practice: Does the *perception* of pain count as data? If so, what would be the fundamental unit of measuring perception of pain? The realist ontological stance that the definition of data seems to be based upon would suggest that to understand pain, one must build from objective indicators of pain that exist, independent of interpretation and human thought. Therefore, would the only valid measure of pain be an increase in heart rate, diaphoresis, or other "objective" somatic measures? What would this then mean for nursing knowledge that "pain is whatever the person

says it is" and the body of research that validates the knowledge that self-reported pain is most accurate, with physiological and nonverbal measures considered less reliable?[42,43] This example illustrates only a few of the unavoidable complexities and limitations of understanding data as it is currently narrowly defined in the DIKW model.

Next, consider the concept of knowledge. In the DIKW model, *knowledge* is described as a product of pattern recognition, identification, and formalizing of interrelationships between various types of information.[3,6,44] However, this depiction of knowledge does not align with developments around epistemological understanding and plurality, particularly in the context of nursing practice. Graves and Corcoran[2] began to point to limitations of DIKW with regard to incorporating the 4 "fundamental patterns of knowing" as identified by Carper[38,39]: "(*a*) *empirics*, the science of nursing; (*b*) *esthetics*, the art of nursing; (*c*) the component of a *personal knowledge* in nursing; and (*d*) *ethics*, the component of moral knowledge in nursing." Graves and Corcoran[2] highlighted that, at the time, conceptualizations of *knowledge* in DIK referred only to empirical knowledge. They therefore pointed to the need for further development in incorporating the other types of *knowledge* central to nursing: aesthetics, personal knowledge, and ethics.

Nursing discourse around knowledge has developed substantially since Carper's initial work, and the history of knowledge development in nursing illustrates wide-ranging epistemological diversity. Much of the work relates to the explication of the types of knowing outlined by Carper; the development of nursing as a science; the emergence of nursing theories and frameworks; the incorporation and application of interpretive and critical approaches; and the growth in prominence of evidence-based practice.[28]

Despite the developments in our understanding of the nature of knowledge and recognition of the distinctive epistemological diversity and information processing used by nurses, there is yet to be evidence that

Graves and Corcoran's[2] suggestion of incorporating an expanded view of *knowledge* has been incorporated in contemporary understandings of DIKW. Arguably, many descriptions of DIKW suggest that reaching *wisdom* requires the marriage of not only different types of knowledge but also of experience, history, context, values, ethics, and aesthetics, suggesting that nursing intuition and tacit knowledge may have valuable contributions to the DIKW model that have remained fairly unexplored.

## DIKW WITH A DUAL PURPOSE

In much of the literature, reference to DIKW in nursing suggests that it is understood as applicable to both systems and nurses as users, perhaps concurrently. DIKW is discussed as a model used for nursing informatics, but it is unclear if this refers to the computer system or the nurse working with it. Although not explicitly articulated, descriptions of DIKW likely presume a fluid relationship between computer system and the nurse and view the interaction between both as part of a larger system. Nevertheless, role boundaries and contributions of both the computer system and the nurse will vary depending on the nature and purpose of the computer system, the nurse's familiarity with the system and related factors (eg, complexity of technology, nurse's level of digital literacy), and the context within which the interaction between the nurse and the system takes place. For example, consider again the concept of pain. In the case of a simple computerized clinical information system, the system may process raw *data* (diaphoretic, 140, heart rate, wincing) to put out *information* (heart rate = 140 + diaphoretic + wincing = pain?*). The nurse may then be expected to incorporate

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*This simplistic example serves only to illustrate the authors' point and presumes the nurse's comprehensive assessment of the situation to rule out that another potential reason (eg, pulmonary embolus) has taken place.

this information either into a broader *knowledge* base (signs of pain + recent surgery = need for acute pain management) or into a history of observations to facilitate actions that demonstrate *wisdom* (the patient who underwent recent surgery with frequent complaints of pain uncontrolled by current medications suggests the need to revise pain management). In the case of a more advanced clinical information system, the system may display characteristics of *knowledge* by recognizing complex patterns and creating recommendations (frequency of pain medication administration + dosage + type of drug = suggestion of change in the type of medication). The nurse can then draw from his or her own *knowledge* base to assess the system's recommendations (ie, evaluate system recommendation in relation to history of tolerance to newly recommended medication) and to apply *wisdom* in deciding whether or not to pursue the system's suggested recommendation (patient's history suggests poor effect of newly suggested medication combined with nurse's recognition of the subjectivity of all pain experiences), leading the nurse to explore alternative options or augment with nonpharmacological approaches to pain management that have provided relief in the past).

In a similar example, Nelson and Staggers[4] describe the potential variability in treating something as data, information, or knowledge, depending on the individual. Whereas a novice nurse may treat something as data, a more experienced nurse may treat it as information.[4] These examples illustrate the variability in the application of DIKW as related to potential combinations of how the computer systems and nursing practice might function. The lack of clear demarcation where DIKW is concerned with computerized clinical information systems and where it is concerned with the nurse, and the role and contributions of each, arguably creates challenges in understanding how the model is meant to be taken up and applied and what purpose it serves. The fluid dynamics between the roles of the computerized clinical information systems and the nurse appear implicit in DIKW Nevertheless, delineation of which concepts refer to the computerized clinical information systems, the nurse, or both, whenever possible, can provide guidance as to how DIKW can be understood and applied.

## WHAT LEVEL OF THEORY DOES DIKW ESPOUSE?

The second guiding question offered in this article is the consideration of the level of theory in DIKW. This aspect of DIKW has not been critically examined, yet this question has many important implications for the understanding and application of the model, particularly given the nursing's history related to theory building. Nursing's transition from an apprenticeship model to a scholarly practice discipline spurred a substantial interest in establishing disciplinary boundaries that included development of various nursing theories, beginning in the 1950s to the 2000s.[45] Following this work was the attempt to understand and tease apart various "levels" of theory within nursing to gain clarity of their purpose and application.[45,46]

It is important to acknowledge that diverse referents of the word *theory* can cause confusion, and it is beyond the scope of this article to delve deeply in this discussion. For guidance, however, Higgins and Moore[46] suggest that it is more useful to use the terms "theory," "theoretical/conceptual model," "theoretical framework," and "theoretical system" interchangeably, with the addition of modifiers such as "grand" or "middle range," to describe a theory's fit among other theoretical work.* In contrast, Nelson

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*A *meta-theory* is a theory of theories that examines overarching theoretical approaches to inquiry and addresses "questions science cannot answer."[46,47] A g*rand theory* is an abstract theoretical system that attempts to provide a universal explanation for a complex phenomenon.[4,46] A *middle-range theory* attempts to explain specifically defined phenomena and can be either explanatory or predictive.[4,46] Middle-range theory has a lower level of

and Staggers[4] make clear distinctions differentiating between theory and conceptual and theoretical frameworks and models and refer to DIKW as one of many theoretical models (ie, a visual representation of a theoretical framework) of information theory. For the purpose of this discussion, theory is defined as "the creation of relationships among two or more concepts to form a specific view of a phenomenon."[46(p179)] Arguably, the current conceptualization of DIKW in nursing informatics falls under this definition of a theory, as (1) it suggests specific relationships among its constituent concepts; and (2) the relationship between concepts suggests a specific process through which wisdom is arrived at. Given the limited critical examination of DIKW in nursing informatics, it is arguable that some of the challenges in understanding the utility and applicability of DIKW that have been highlighted stem from the description of DIKW as a grand theory yet incorporating concepts and features of middle-range theory.

DIKW falls under the criteria of a grand theory, as it outlines a theoretical framework of abstract concepts with specific relationships that attempt to explain a specific phenomenon (the movement from data to wisdom), with limited capacity for empirical testing. However, DIKW also has features of middle-range theory such as having implicit philosophical assumptions, being sufficiently general to cross multiple clinical populations, and providing specifics to guide research and practice.[46] DIKW explicitly outlines each step of the theoretical framework and provides clear direction as to how data can be processed and transformed from discrete entities to components of a complex knowledge base and further, describing how arriving at wisdom ultimately guides clinical practice and decision making. Although DIKW can be viewed

as an explanatory middle-range theory, it does not meet the criteria for empirical testability. Specifically, the means through which to measure or observe the transformation from data to each subsequent is unclear. In addition, the diversity of ways that wisdom is conceptualized and modeled would suggest different approaches to its measurement and confounded by the added complexity of placing it in context of the DIKW theoretical model.[19]

The notion that DIKW lies somewhere between a middle-range theory and a grand theory is supported by Nelson and Staggers, who suggest that theoretical frameworks can be "conceived as a bridge between a middle range theory and a grand theory."[4(p19)] Indeed, it may be the case that DIKW is similar to Jean Watson's *Philosophy of Science and Caring* and Madeleine Leininger's *Culture Care: Diversity and Universality Theory*, where no consensus has been reached on whether it is grand or middle-range theory.[46] Considering this possibility, one way of reframing how DIKW is viewed is to see it as an indicator of the evolution of disciplinary nursing knowledge.[46] DIKW is well entrenched in nursing informatics and perhaps some effort in revisiting this theoretical model may be worthwhile. Further explication and delineation the levels of theory incorporated in DIKW can highlight important questions. Potential avenues for inquiry include investigation of what components of DIKW are empirically testable, the development of measures and tools to test the theoretical model, and the exploration of conceptual models that are perhaps embedded within the larger framework. Indeed, these and other points are addressed in some recent attempts in moving forward with the continued evolution of DIKW in nursing informatics, as will be described in the following section.

## CONCLUSIONS

The proposed flexibility in the most recent DIKW model illustrates the ongoing development and progress in the understanding and attempts to operationalize DIKW in nursing

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abstraction and is empirically testable, whereas grand theory is at a higher level of abstraction and is not testable.[48] Finally, *micro-range theory* is the most narrow in scope and can take the form of a specific research hypothesis.[4,46]

informatics. Building on the ongoing work on the evolution of DIKW, this discussion argued that the perspectives of DIKW in nursing informatics might be made richer with the incorporation of the criticisms of DIKW from disciplines outside of nursing, for example, the critiques of linearity and hierarchy as outlined by Tuomi[26] and Faucher et al[17] from the field of management information systems. Similarly, criticisms from the field of information science highlighted the implications of the philosophical underpinnings of DIKW on its potential application.

In this discussion, 2 key guiding questions were offered, with the aim of clarifying underpinnings of DIKW, so that its application may be better informed. First, the question of who or what DIKW is meant to serve has been elucidated, highlighting the differences and implications of DIKW as applied solely to computerized clinical information systems, as applied solely to nursing practice, and as applied to systems that incorporate both. The second guiding question involved the questioning and examining of the level of theory DIKW is thought to occupy (ie, somewhere between a grand theory and a middle-range theory) and how this lack of clarity, in the past, has likely contributed to some of the challenges in applying and operationalizing DIKW.

Alternatively, perhaps DIKW can be viewed as a vision or goal for nursing informatics: a depiction of nursing informatics as a vehicle in the movement toward nursing praxis. In other words, using nursing informatics to arrive at "theory and practice that are interrelated, integrated, and dialectal in nature"[49(p126)] and that has as an inherent component "the notion of reflection upon practice toward the refinement of theory and therefore the enhancement of practice."[50(pxii)] In this view, we would then be directed to taking up DIKW as a means of understanding nursing informatics, inclusive of both computerized clinical information systems and nurses as users, since nursing praxis would require both components. In addition, if DIKW is understood to be a

vision for nursing informatics in moving toward nursing praxis, further development of the model is needed to better explicate the complexities that are unaddressed in its current visualized form.

It is worth highlighting that continued interest in the concepts in DIKW remains in nursing informatics. The most recent work by Matney[15] on the development of the Theory of Wisdom-in-Action for Clinical Nursing can be seen as an exemplar of moving the concepts within DIKW forward, particularly the much understudied concept of wisdom. Matney's theory proposes person- and setting-related factors as antecedent dimensions of wisdom and 2 types of wisdom processes: general wisdom-in-action and personal wisdom-in-action. We argue that part of what has facilitated the clarity and operationalization in Matney's theory development includes meeting the clearly and explicitly addressing the 2 guiding questions brought forward in this article: (1) who/what does it serve (the Theory of Wisdom-in-Action specifically looks at clinicians in practice); and (2) the clear delineation of the level of theory it aims at, specifically, as a mid-range theory that is potentially testable.

Works such Matney's[15] Theory of Wisdom-in-Action and philosophical approaches to DIKW,[6] as well as application of DIKW by Gee et al[13] and by Looman et al,[14] suggest that part of the continued attraction of DIKW in nursing informatics is its ability and continued potential for making visible aspects of nursing work in the move toward increasingly digitized systems. Although not without its challenges, perhaps taking different philosophical approaches to understand various components of DIKW as suggested by Matney and colleagues,[6] is one way of moving forward, making possible the potential for eventually including and operationalizing Carper's ways of knowing in nursing informatics.

Finally, we point to the potential for moving toward more interdisciplinary dialogue, as related to DIKW. At this time of writing, we are unable to identify any articles that

use or examine DIKW from more than 1 disciplinary perspective and highlight this as a potentially fruitful area of inquiry in the future. At the outset of this article, we posited that an approach such as DIKW can provide a common language and coordination of individuals from various disciplines (eg, nursing, computer science, information science, medicine). In closing, we would note that true *inter*disciplinary dialogue, where we "analyze, synthesize, and harmonize the links between our disciplines into a coordinated and coherent whole,"[51(p351)] is required if we are going to be able to enhance the development and application of the DIKW model for health care overall. We hope this discussion further contributes to continuing understanding of DIKW in nursing informatics and its evolution and toward the goals of nursing informatics to be able to incorporate different types of knowledge in nursing as part of computerized clinical information systems, as initially described by Graves and Corcoran, and toward the larger goal of nursing informatics of making nursing work visible.

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