

A Novel Quantitative Approach to Concept Analysis: The Internomological Network

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Abstract

Background—When a construct such as patients' *transition to self-management* of chronic illness is studied by researchers across multiple disciplines, the meaning of key terms can become confused. This results from inherent problems in language where a term can have multiple meanings (polysemy) and different words can mean the same thing (synonymy).

Objectives—To test a novel quantitative method for clarifying the meaning of constructs by examining the similarity of published contexts in which they are used.

Method—Published terms related to the concept *transition to self-management* of chronic illness were analyzed using the internomological network (INN), a type of latent semantic analysis to calculate the mathematical relationships between constructs based on the contexts in which researchers use each term. This novel approach was tested by comparing results to those from concept analysis, a best-practice qualitative approach to clarifying meanings of terms. By comparing results of the two methods, the best synonyms of *transition to self-management*, as well as key antecedent, attribute, and consequence terms, were identified.

Results—Results from INN analysis were consistent with those from concept analysis. The potential synonyms *self-management*, *transition*, and *adaptation* had the greatest utility. *Adaptation* was the clearest overall synonym, but had lower cross-disciplinary use. The terms *coping* and *readiness* had more circumscribed meanings. The INN analysis confirmed key features of *transition to self-management*, and suggested related concepts not found by the previous review.

Discussion—The INN analysis is a promising novel methodology that allows researchers to quantify the semantic relationships between constructs. The method works across disciplinary boundaries, and may help to integrate the diverse literature on self-management of chronic illness.

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Keywords

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Investigators new to a topic area can be confounded by the terms used to name research constructs. For example, the idea of *self-management* is discussed widely in the chronic illness literature. But self-management researchers may use multiple terms, including *self-care*, *symptom management*, and *disease management*, to reference similar ideas (Richard & Shea, 2011). Because people are less than 20% likely to express the same idea independently using the same words (Fumas, Landauer, Gomez, & Dumais, 1987), problems of *synonymy* (different names for the same construct) and *polysemy* (identically named dissimilar constructs) are common in research. The antecedents, attributes, and consequences of self-management similarly may go by multiple names. In a preliminary analysis, out of 12,876 constructs in 15 journals relevant to the study of self-management (four in nursing, two in psychology, and three each in sociology, business, and education), 7,807 (61%) terms were used only once. In one example, only 28 of 178 self-efficacy constructs were used more than once. Researchers thus may unknowingly duplicate past work, or study noninformative correlations between constructs that are simply two different names for the same thing (Efran & Cook, 2000).

The Current Solution: Concept Analysis

The best available method for resolving problems of synonymy and polysemy is Wilson's (1963) method of *concept analysis*, a qualitative approach using structured literature review to identify synonyms or "surrogate terms" for a given construct, as well as its antecedents (events prior to occurrence of the construct), attributes (typical or recurring features of the construct), and consequences (events that result from the construct; Walker & Avant, 2010). Such causal relationships are key factors that help to establish a construct's meaning (Connell & Keane, 2004). Attention to the context in which a construct is used also helps researchers to understand that construct's meaning in a particular literature at a particular point in time (Rodgers & Knafl, 2000). One problem with concept analysis is the qualitative nature: Although the process is structured, individual researchers may arrive at different conclusions about the core meaning of a construct; related terms; and whether related terms are synonyms, antecedents, attributes, or consequences. Another limitation is that although concept analysis is well-known in nursing, it is virtually unknown in disciplines like psychology, education, preventive medicine, and health care administration. This limitation is particularly relevant in the self-management literature, where investigators publish from many disciplinary perspectives.

Although concept analysis can cross disciplinary lines, researchers tend to use their own discipline's characteristic terminologies and methods. This leads to the problem of synonymy when related constructs evolve independently. Finally, borrowing from other disciplines is likely in inherently transdisciplinary fields like self-management research. Each discipline brings its own perspective that may strengthen existing theories, but interdisciplinary work may have the disadvantage of polysemy when researchers misuse or reinterpret terms originally developed in other fields.

Concept Analysis in the Self-Management Literature

The problem of multiple terminologies is illustrated by the concept of transition to self-management of chronic illness. Half of Americans now take medication for one or more chronic diseases (Medco Health Solutions, 2008), and self-management has become an essential part of public debate about how to control United States health care costs. For

adults, self-management involves multiple behaviors: taking medications, exercising, healthy eating, smoking cessation, self-monitoring signs and symptoms of disease, identifying and avoiding triggers for illness flare-ups, managing emotional reactions to illness, navigating health care systems, and negotiating social roles affected by a disease. These tasks are relatively consistent across chronic disease states (Clark, Becker, Janz, & Lorig, 1991), although disease-specific medications, monitoring techniques, and knowledge are needed. Each aspect of chronic disease self-management is a concrete behavior that patients must adopt, and the process of initiating these behaviors at the onset of disease--the *transition to self-management* of chronic illness--is of particular interest to researchers and clinicians. Multiple disciplines study self-management using different terms, including nurses, psychologists, educators, and business professionals in disease management. This construct is therefore in need of clarification to provide a consistent focus for transdisciplinary research.

A concept analysis was completed previously of *transition to self-management* in adults (Sakraida, Pedro, Cook, & Bent, 2006). The authors have education and training in multiple disciplines (nursing, psychology) and clinical areas (diabetes, cancer, mental health), and specifically worked toward a transdisciplinary synthesis. Following a review of literature, consensus was reached on the synonyms, antecedents, attributes, and consequences of *transition to self-management*. Although a best-practice evolutionary method (Rodgers, 1989) was used to clarify this construct's meaning, the construct could be elaborated further.

A Quantitative Approach to Concept Analysis

To address limitations of qualitative reviews, the second author developed a quantitative approach based on latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1998). This method is used to determine mathematically the similarity of meaning between constructs. The underlying premise is that the aggregate of all contexts in which a given word does and does not appear provides a set of constraints that defines its meaning. Thus, when two terms occur in similar contexts, even if they never occur together, LSA represents them as having similar meanings.

In the combination of LSA and construct content, termed the *inter-nomological network* (INN; Larsen & Hovorka, 2012), all papers with at least one behavioral construct published in leading research journals are analyzed to create a semantic space, which becomes a tool through which other texts may then be examined. To create the semantic space, second author's research team began by selecting top journals in the nursing, psychology, business administration, and education disciplines (Table 1), based on recommendations from experts in each discipline. All articles were parsed from multiple years of each journal into paragraphs, then each paragraph was treated as a document (Larsen & Monarchi, 2008); these were parsed to extract individual words. Using Porter's (1980) algorithm, each term was then "stemmed" to treat multiple versions of the word as the same, for example "nurse" and "nurses." At that point, "a corpus of d artifacts (e.g., documents or paragraphs) containing t stemmed words (terms) is represented as a tXd term-frequency matrix \mathbf{A} " (Larsen & Monarchi, 2004, p. 354). The \mathbf{A} matrix is weighted using a log-entropy approach (Berry & Browne, 1999) to reduce the importance of high-frequency terms such as conjunctions while emphasizing distinct terms, and each column is normalized to a length of 1 (Larsen & Monarchi, 2004).

The resulting matrix is submitted to singular value decomposition (SVD), an approach mathematically related to principal components analysis and factor analysis in general (Wall, Rechtsteiner, & Rocha, 2003), resulting in a *semantic space* where each stemmed term and document is represented by a high-dimensional vector. In the current analysis, SVD was used to represent each term as a vector with 500 dimensions, and to project it into

the semantic space as a pseudodocument (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990). Finally, a vector describing each construct's relationship with all other constructs was stored in a new *meta-semantic space* consisting exclusively of these measurement vectors.

The numeric results utilized in this approach to INN analysis are cosine values that indicate the strength of relationships between constructs. The strength of the semantic relationship between any two constructs is quantified based on the cosine between their vectors in the meta-semantic space (Larsen & Monarchi, 2004). Cosine values are simply a transformation of the angle between two vectors, where the smaller the angle, the higher the cosine and the stronger the relationship between the two constructs.

Aims of the Current Study

In the current study, the novel INN methodology was applied to an existing research problem, describing the construct *transition to self-management* and its relationship to other terms in the literature. The aims were to (a) examine INN analysis as a novel quantitative method for clarifying the meaning of constructs, using the example of *transition to self-management*; (b) evaluate the usefulness of INN analysis in identifying terms related to *transition to self-management* across disciplinary boundaries; and (c) compare and contrast INN analysis results to those from concept analysis, a best-practice approach. Finally, key features of *transition to self-management* were identified based on combined findings from INN and concept analysis. Because different methods were used in the INN analysis and the concept analysis, they were based on different bodies of literature (i.e., hand-selected key journals for the INN versus standard search engines for the concept analysis), and included literature from a different set of disciplines. It was expected that the two approaches would yield partially independent, but potentially complimentary results.

Method

Materials

Concept analysis—The concept analysis used for comparison to INN results was completed in 2006–2007 (Sakraida, Pedro, Cook, & Bent, 2006) using the evolutionary method (Rodgers, 1989). The past 10 years of publications indexed in search engines for nursing (CINAHL), psychology (PsycINFO), and medicine (Medline) during the years 1990–2006 were searched using any of the terms *self-management*, *adaptation*, *adjustment*, or *coping*, all of which matched to subject headings in each of the three databases. Keyword searches were performed on the terms *transition*, *readiness*, *development*, and *change*, potentially related concepts that did not map to subject headings. Abstracts were hand-screened for relevance. Potentially relevant articles were retrieved and hand-coded; multiple publications by the same first author were excluded to avoid overrepresenting one investigator or research team's understanding of the transition to self-management in the final results. Rodgers recommends a sample of at least 30 articles to describe a concept. The final sample included 33/38 relevant articles from psychology, 30/32 from nursing, and 30 randomly selected from 456 in medicine. The final sample therefore included 17% of available self-management articles at the time of the review. From each article, the reviewer identified antecedents, attributes, and consequences of *transition to self-management*, as well as contextual variations, surrogate terms, and related concepts. The process took about 100 person-hours to review literature and achieve consensus (Sakraida, Pedro, Cook, & Bent, 2006).

Internomological network—The current version of the INN database contains 3,236 parsed articles from 15 key research journals in business, general psychology, education,

sociology, and nursing, which reference 12,876 constructs. Using this existing database, each INN query took less than 5 seconds. The INN is accessed through a web browser interface, with queries based on a user's entry of keywords generating a set of variables that directly contain those keywords. The user then selects a variable to view a list of similar constructs sorted by *cosine*, which is a measure of the contextual similarity between two constructs. Constructs used in identical contexts have a cosine of 1, and constructs that appear in completely dissimilar contexts have a cosine of 0. High cosines do not necessarily indicate that two constructs have the same meaning, but do suggest that researchers use them in similar situations.

Data Analysis Strategy

Internomological network analysis has similarities to exploratory factor analysis (EFA). Like EFA (Cronbach & Meehl, 1955), INN is an empirical approach to quantifying relationships between language units: in EFA, items on a scale, and in INN, constructs within articles. For both methods the final results depend on an investigator's ability to recognize and interpret mathematical patterns in the data. Based on these similarities, the steps for INN analysis paralleled the steps of EFA.

Analysis of results—In EFA, the investigator first determines how much variability can be accounted for by each identified factor, with the highest eigenvalue identifying the factor accounting for the most variability in the original instrument. Second, the investigator examines how strongly individual scale items load on each factor and suggests a descriptive label for each set of items. Similarly, the INN query results were examined for each of five potential synonyms of *transition to self-management* identified in the concept analysis: *self-management*, *transition*, *coping*, *adaptation*, and *readiness*. The terms with the largest cosine-based relationships with other constructs were determined based on the assumption that terms with larger cosines are associated more robustly with other terms and may be understood more readily, especially across disciplinary boundaries. This process was followed by examining the cross-disciplinary reach of each synonym term, based on the disciplinary affiliation of journals in which it appeared.

Comparison to concept analysis results—In the original concept analysis, seven antecedent terms, four aspect or attribute terms, and six consequence terms were identified related to the concept *transition to self-management* (Sakraida, Pedro, Cook, & Bent, 2006). Each of the top 50 INN results for each of the five search terms was classified as representing one of these 17 related terms, or as representing none of them. This stage of analysis is analogous to the examination of individual items in EFA, which helps to identify key aspects of a construct. In a few cases where a duplicate term appeared in the top 50 results (same construct name and same authors), the result with the higher cosine was retained, the second result was skipped, and the query was expanded to keep the total number of results at 50 per search term. Three of the four initial concept analysis (Sakraida, Pedro, Cook, & Bent, 2006) authors rated each INN search result independently. The reasons for the coding of each INN result were compared and discussed until a consensus was achieved through discussion. Raters' original codes were recorded, interrater reliability (kappa) was calculated, and final consensus results were used for analysis. With three raters, the process for coding results from all five INN queries took 21 person-hours. The number of antecedents, attributes, or consequences related to each INN search term was examined to measure the breadth of meaning captured by each potential synonym of *transition to self-management*.

It was noted which of the original concept analysis (Sakraida, Pedro, Cook, & Bent, 2006) results matched the INN results for each potential synonym term, which were not well-

represented in the INN results, and which INN results did not match the original categories, suggesting potentially meaningful features of the transition to self-management that were missed in the original approach. Finally, the related constructs most frequently found across all five INN search terms were summarized as a method to identify the key antecedents, attributes, and consequences of *transition to self-management*.

Results

Synonyms of Transition to Self-Management

The first 10 INN query results for each of five potential synonyms of *transition to self-management* are shown in Table 2. Results for the terms *self-management*, *adaptation*, and *coping* had the highest cosines, indicating the most consistent semantic relationships to other terms. The terms *transition* and *readiness*, with lower cosines, were used more broadly and may be meaningful in a wider variety of contexts. However, breadth of meaning is a potential liability in scientific communication, where it is necessary to utilize terms with a particular circumscribed meaning in a consistent set of contexts. The terms *self-management*, *coping*, and *adaptation* have the greatest conceptual clarity and therefore may be most useful in scientific communication.

From the data in Table 2, INN results were identified that were clearly not relevant to chronic disease self-management. The term *self-management* had associations with employee management in nursing and business; *transition* had associations with organizational functioning and job transitions such as retirement; and *coping* included studies of general functioning that were unrelated to chronic disease. Such superfluous meanings may complicate the use of each term to describe patients' transition to self-management of chronic diseases. The term *adaptation* most consistently produced results related to chronic disease, with only one other result that related to the process of disseminating scientific results into practice settings.

Cross-Disciplinary Utility of Terms

A second way to interpret the results in Table 2 is by the disciplinary origin of constructs. Terms used by a greater number of disciplines may have greater cross-disciplinary currency and can be helpful in collaborating and in presenting one's findings. How many of the top 10 INN results for each term came from each of four disciplines is shown in Figure 1. The terms *self-management* and *transition* were used by the most disciplines, with *transition* having the broadest cross-disciplinary use. *Self-management* most often had results from the business literature, in which many of the terms referred to one person managing another's work. The terms *coping* and *adaptation* were most common in the nursing literature, with a few references in psychology, and the term *readiness* was distributed about evenly between nursing and psychology.

Researchers presenting self-management studies in interdisciplinary venues may find it useful to describe their research using terms with greater recognition across disciplinary lines. However, despite the cross-disciplinary utility of the term *transition*, this concept also had lower INN cosine values, a pattern of results that may suggest the problem of polysemy if a term is used inconsistently or with different meanings across disciplines. The term *self-management* had higher cosines, but based on the different meanings of *management* in a business context, the problem of polysemy may be an issue for this concept as well. The term *adaptation* avoided this problem, but was used rarely outside the nursing literature.

Comparison to Concept Analysis Results

The left-hand column in Table 3 lists antecedents, attributes, and consequences identified in the previous concept analysis (Sakraida, Pedro, Cook, & Bent, 2006). Rows show the number and percent of the top 50 results from each INN query that matched each of these 17 terms. Interrater reliability was high for these categorizations; average $| = .91$, with a range from $| = .83$ (*adaptation*) to $| = .98$ (*readiness*).

The INN results for the terms *transition* and *adaptation* included the most related constructs. The greatest number of results for both terms matched the antecedent *existing ecological system*, which described personal, interpersonal, and other resources available to the person experiencing a transition to self-management. Results for both *adaptation* and *transition* were linked to the attribute *behaviors or actions*, but only *adaptation* was linked to the attribute *response to situation: cognitive, emotional, values, motivation*. The term *transition* thus appears to capture mainly a behavioral response to self-management and may omit the idea of a cognitive or emotional response; when discussing such responses, the term *adaptation* may have a clearer meaning. Search results for *transition* included several items related to the *unstabilizing event* antecedent, while results for *adaptation* did not. The term *transition* was also unique among the five search terms in tapping the consequence *sense of control*. Despite the broad range of related concepts tapped by *transition*, this term also had the highest number of unclassifiable results, which may suggest that it has less clear relevance or a broader range of usage outside the context of chronic illness self-management. These findings are consistent with the lower average cosine results for *transition*, suggesting a less clear and consistent meaning.

For the term *self-management*, more than half of the related terms were found in INN query results, with the most results again corresponding to the antecedent *existing ecological system* and the attributes *behaviors or actions* and *response to situation: cognitive, emotional, values, motivation*. Like the terms *transition* and *adaptation*, *self-management* was linked to the antecedent *personal readiness*, but *self-management* also tapped the antecedent *coping style* and the attribute *navigating systems*, which were not seen in results for the other two terms. Three *self-management* query results were related to the consequence *partnerships* with health care providers or support networks, an idea seen only once in results for *adaptation* and not at all in results for *transition*. However, *self-management* failed to tap several constructs found in one or both of the other terms' search results including *emotional reaction to situation*, *developmental process*, and *sense of control*. Overall, compared to the terms *transition* and *adaptation* the term *self-management* appears to tap a greater range of meanings related to healthcare and social systems, but fewer meanings related to a person's individual experience and response to illness.

The terms *readiness* and *coping* had more circumscribed meanings. For *coping*, nearly 40% of INN search results corresponded to the attribute *response to situation: cognitive, emotional, values, motivation*, with many also matching the antecedent *coping style* and the attribute *behaviors or actions*. For *readiness*, more than 60% of INN results matched the antecedent *personal readiness for transition, knowledge, or skills*. The second most strongly related term for *readiness* was the antecedent *existing ecological system*. *Coping* and *readiness* thus had relatively specific meanings and did not cover the full range of related terms. These terms may be useful in describing some features of *transition to self-management*, but do not capture the construct's full range of meanings and are probably not fully synonymous with it.

Key Features of Transition to Self-Management

The total number of times each of the 17 terms identified in the concept analysis was found across all five INN searches is shown in Figure 2. Based on these results, the key features of *transition to self-management* are the antecedents *existing ecological system* and *personal readiness*, the attributes *behaviors or actions* and *response to situation: cognitive, emotional, values, motivation*, and the consequences *escaping from burden of illness* and *partnerships*. Consequence terms were least often seen overall in INN results and may represent conceptually different constructs. The consequence terms *stability of personhood* and *hopefulness*, identified in the original concept analysis (Sakraida, Pedro, Cook, & Bent, 2006), were not represented in the 250 INN query results, and consequence terms altogether were found less than 2% of the time. Antecedent terms were identified most frequently, representing 52% of all INN query results.

Additional Terms Related to Transition to Self-Management

Slightly over 13% of INN query results were not classifiable based on the related constructs found in the concept analysis. The authors kept notes on the meaning of these terms and why they were considered not applicable. While some concepts were clearly unrelated to chronic disease (e.g., power differentials within organizations, employee performance on a road crew, or job transitions), others suggested areas where the concept analysis could be improved. The authors noted that an additional category was needed to capture previous life experiences. For instance, past experiences of moving or living in a foreign country might shape how individuals approach the transition to self-management of illness. The authors also noted that the attributes and consequences of *transition to self-management* in the original concept analysis (Sakraida, Pedro, Cook, & Bent, 2006) were almost exclusively psychological, and that an additional category was needed to capture physiological changes. Representative INN results included hemoglobin A1c and blood pressure, which could change as consequences of a successful transition to self-management. Finally, the concept analysis was weak in coverage of family and culture, and could be improved by adding an antecedent specifically related to cultural understandings and values.

Discussion

This study presents the first use of a new tool for clarifying constructs' meanings, the INN. The analysis was used to examine relationships between terms used across multiple disciplines to describe the transition to self-management of chronic illness. Quantitative results from five INN queries were compared to results from concept analysis, an established best-practice qualitative method based on a structured literature review and expert consensus. Overall results suggest that INN analysis is a useful tool to establish the meaning of constructs. The INN, which is an empirical, quantitative method for identifying conceptual links between constructs based on the similarity of written contexts in which the terms have been used, produced results strongly linked to 17 antecedent, attribute, and consequence terms from the authors' previous concept analysis of *transition to self-management*. Furthermore, INN analysis tapped constructs from previously unconnected literatures in nursing, psychology, business, and education.

Findings about the Construct *Transition to Self-Management*

The INN analysis allowed findings from the previous concept analysis of the term *transition to self-management* to be clarified and extended. The potential synonyms of *transition to self-management* with the greatest conceptual clarity were *self-management*, *adaptation*, and *coping*. The term *adaptation* had the best conceptual clarity overall, but was rarely seen outside the nursing literature and might be most useful when addressing audiences within the discipline of nursing. The terms *self-management* and *transition* had the greatest cross-

disciplinary relevance and may be more useful to self-management researchers when speaking to broad audiences of researchers, health care providers, and policy-makers. However, the term *transition* may be more vulnerable to polysemy, having different meanings for different audiences. Such additional meanings enhance understanding of a concept (Walker & Avant, 2010) but may complicate its use in scientific contexts. The term *self-management* had clearer meaning but also tapped some unrelated organizational management content from the business literature. The terms *transition*, *adaptation*, and *self-management* all showed considerable overlap with a range of antecedent, attribute, and consequence terms from the original concept analysis. The terms *coping* and *readiness* had more circumscribed meanings and may not be true synonyms for *transition to self-management*.

The original concept analysis (Sakraida, Pedro, Cook, & Bent, 2006) could be improved by describing the *transition to self-management* in terms of just a few key antecedents (*existing ecological system* and *personal readiness*), attributes (*behaviors or actions* and *response to situation: cognitive, emotional, values, motivation*), and consequences (*escaping from burden of illness* and *partnerships*). Some terms were not found in INN results and may be related less strongly to *transition to self-management*. Alternately, these findings may indicate gaps in coverage for the current INN database that will be corrected as more journals are indexed. Other terms identified in the original review showed moderate semantic relationships to self-management, with 87% of INN results mapping to previously identified terms. Finally, INN results suggested that the concept analysis could be improved by adding antecedents related to culture and experience, and a consequence related to the physiological outcomes of transition to self-management. These findings highlight the use of INN analysis to find semantic relationships between previously unrelated constructs and to suggest directions for future research.

Comparison of INN Analysis to Other Available Methods

Internomological network analysis is a novel methodology that should be considered in relation to other available methods for examining semantic relationships between constructs. The most common approach to clarifying the meaning of constructs is a qualitative review such as concept analysis, which in this study was used as a comparison condition. The INN analysis compared favorably to this approach, producing results that replicated prior findings in a much more time-efficient manner--21 versus 100 person-hours--and extending those results with additional semantically related constructs from the literatures of several disciplines. The additional findings obtained through INN analysis highlight the usefulness of combining approaches. Concept and INN analysis methods may have different strengths and may each be useful as steps in the evolutionary process of developing shared meaning for scientific terms (Rodgers & Knafl, 2000).

Currently available alternatives to INN include citation analysis, automatic text analysis, and meta-analysis. Citation analysis is used to examine reference trail links between papers, but cannot be used to assess relationships when authors omit pertinent citations. This method also remains vulnerable to the problems of synonymy and polysemy. Automatic text analysis is a promising approach (LSA is one type of automatic text analysis), but to date abstracts or full papers have been used as the unit of analysis. This limits the method's utility for studying meanings at the construct level. The INN method overcomes this limitation (Larsen & Monarchi, 2008). Complexity and lack of off-the-shelf software for automatic text analysis are other barriers. Finally, meta-analysis is a mathematical, cross-disciplinary approach for combining research findings, but can introduce bias based on inclusion and exclusion criteria for the literature review. These are not set *a priori* in INN analysis. Meta-analysis is vulnerable to synonymy and polysemy, and only includes relationships between constructs that have been tested and reported. By contrast, INN

provides data on constructs' semantic relationships based on the contexts in which they are used, even if two constructs never have been studied together. Many of these approaches may be complimentary, and future development of the INN database may incorporate features of other methods.

Recommendations

A preliminary INN nursing research database is freely available online at <http://inn.colorado.edu/> for investigators who wish to test this resource in their own areas of science. Although the approach compared INN results to those from an existing concept analysis, many of the steps could be used without having previous results available. In the suggested process for INN analysis, which parallels the steps of EFA, investigators would (a) identify one or more potential synonyms for a construct of interest; (b) use these synonyms as INN search terms and record the top 10 to 50 results; (c) examine the strength of relationship between each term and related terms based on cosines; (d) examine the level of interdisciplinary relevance for each term; and (e) categorize results to identify key antecedents, attributes, and consequences for each potential synonym. The final step of this process requires expert judgment and consensus-building, similar to assigning conceptual names to instrument subscales in the final step of EFA. Analyzing INN results in terms of antecedents, attributes, and consequences is useful even when no previous concept analysis has been done, because a term's meaning is established more by its causal relationships than by its exact synonyms (Connell & Keane, 2004). Using multiple expert raters and calculating interrater reliability may be useful at this stage, but it can be accomplished in a much shorter amount of time than the current best-practice method of concept analysis.

Limitations and Directions for Future Research

One limitation of INN is that while the database overall is perfectly sized based on accepted standards for LSA, the inclusion of literature from five disciplines may make our database less focused than is common for LSA. Lower cosine results for some search terms thus may mean only that our current database does not include the necessary data to adequately categorize these terms. The high level of agreement between INN and concept analysis is particularly encouraging given this limitation, but current findings cannot be taken as definitive.

The second limitation of a small database is that some constructs may not be included because they were not mentioned in the sample of literature used to construct the database, despite their importance in other research. This is a possible explanation for the absence of some of the original concept analysis terms in the INN results. As the INN database expands to include more journals from additional disciplines, this problem will be reduced, but incomplete coverage of all possible journals and research articles is likely to remain a limitation. It is therefore essential to note that the absence of a potentially related term from INN query results may indicate either no relationship between constructs or a gap in INN database coverage with respect to one or both of the potentially related constructs. This is a type II error problem in INN analysis for which further methodological development is needed (e.g., a way to quantify the problem, similar to a *file drawer* calculation in meta-analysis).

Third, in analysis of terms' cross-disciplinary utility, a simple classification was made based on the disciplinary affiliation of the journals in which constructs were published. This ignores the possibility that members of one discipline may publish in another discipline's journals. The first author's degree would have been another way to identify articles' disciplinary orientation, but that approach would ignore the contributions of

multidisciplinary research teams. Further refinement of the INN method to classify and filter search results by discipline is needed.

Finally, both concept analysis and INN analysis require human judgment to sort construct names into broader categories. This may have introduced bias into the results, although the level of subjectivity is no greater than that in other commonly accepted empirical procedures like EFA. The possibility of bias was reduced by using expert raters, calculating interrater reliability, and establishing consensus for each INN search result.

Conclusion

In this study INN analysis, a novel quantitative method to clarify the meaning of scientific constructs, was applied to the term *transition to self-management* in chronic disease. Results from this first use of INN analysis in the nursing literature mirrored results from a prior concept analysis using a hand search of literature and a time-consuming process to achieve consensus. The INN analysis extended those findings by highlighting the strongest semantic relationships between constructs, and by including additional related constructs from four separate disciplines' literatures. The findings support the utility of this novel method as an approach to clarify the meaning of constructs in transdisciplinary scientific fields such as self-management research.

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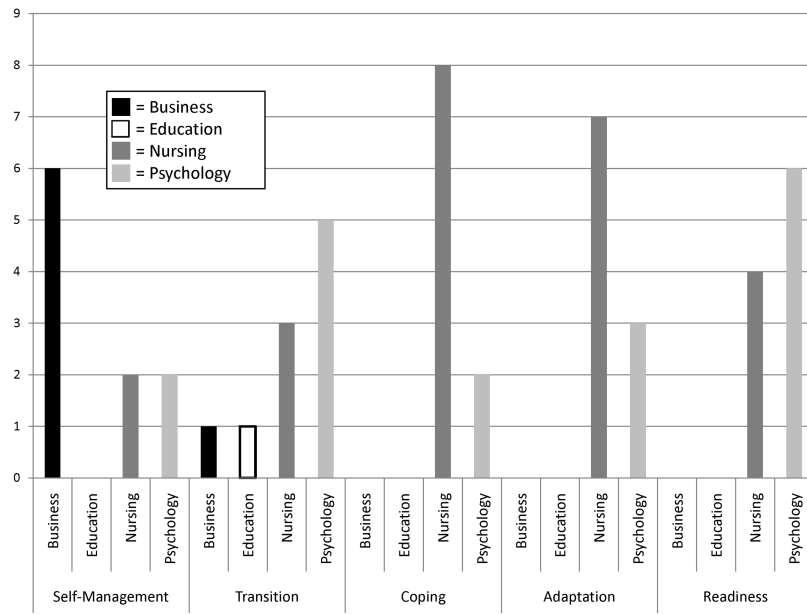


Figure 1. Internomological Network Results per Discipline for Each Synonym of “Transition to Self-Management”

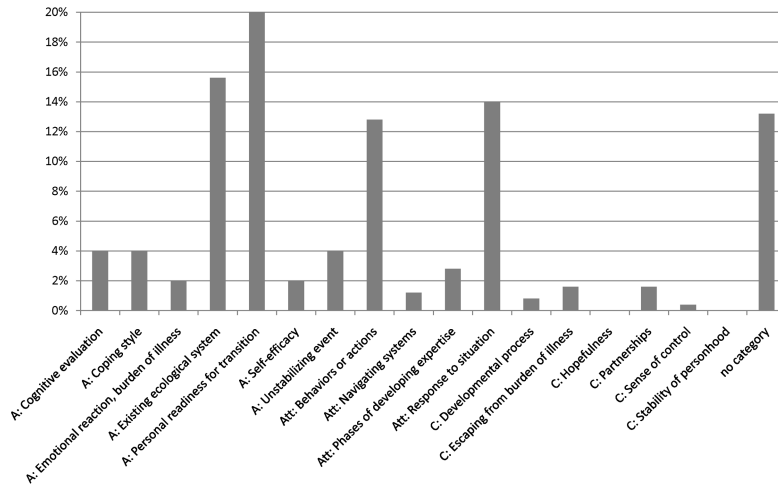


Figure 2.
Combined Internomological Network Results by Category

Table 1

Internomological Network Database Content

Journal	Date Span	Number of Articles
American Educational Research Journal (<i>E</i>)	1988–2007	128
American Journal of Sociology (<i>S</i>)	2000–2009	76
American Sociological Review (<i>S</i>)	2000–2009	118
Educational Evaluation and Policy Analysis (<i>E</i>)	2000–2009	37
Health Education Research (<i>P</i>)	2000–2009	337
Information Systems Research (<i>B</i>)	1990–2009	145
Journal of Applied Psychology (<i>P</i>)	1998–2007	626
Journal of Management Information Systems (<i>B</i>)	1995–2009	218
Journal of Nursing Scholarship (<i>N</i>)	2000–2009	201
Journal of Personality and Social Psychology (<i>P</i>)	2008–2009	289
MIS Quarterly (<i>B</i>)	1980–2009	193
Nursing Research (<i>N</i>)	2000–2009	281
Research in Nursing and Health (<i>N</i>)	2000–2009	293
Social Forces (<i>S</i>)	2000–2009	229
Sociology of Education (<i>E</i>)	2000–2009	65
Total		3236

Note. B = business journal, E = education journal, N = nursing journal, P = psychology journal, S = sociology journal

Table 2

Top 10 Results from Internomological Network Queries

Order of INN Cosine Values for Relationships Between Potential Synonyms and Related Terms					
Results	Self-Management	Transition	Coping	Adaptation	Readiness
#1	.99: epilepsy self-management <i>P</i>	.59: transitions between three stages <i>P</i>	.94: coping mechanisms [in hypertension] <i>P</i>	.99: temperament: adaptability <i>N</i>	.52: stage of change <i>N</i>
#2	.90: manager <i>B</i>	.48: reasons for turnover: retirement <i>E</i>	.83: personal coping capability <i>N</i>	.99: adaptability <i>N</i>	.47: stage of change <i>P</i>
#3	.90: manager <i>B</i>	.48: retired <i>N</i>	.81: perceived coping effectiveness <i>N</i>	.90: adaptive behavior <i>N</i>	.44: precontemplation <i>P</i>
#4	.90: style of management <i>B</i>	.47: peripheral composite [finger temp, finger pulse, ear pulse] <i>P</i>	.81: immediate coping <i>P</i>	.87: adaptation <i>N</i>	.44: contemplation <i>P</i>
#5	.79: impression management <i>P</i>	.37: preintention stage <i>P</i>	.80: coping style: fatalistic <i>N</i>	.80: resilience <i>N</i>	.43: stage of readiness for change <i>N</i>
#6	.76: CV influence: management style <i>B</i>	.35: causes of transition from action to maintenance stage <i>P</i>	.78: coping methods <i>N</i>	.78: dissemination stage: innovation adaptation <i>P</i>	.41: stage transition: precontemplation to contemplation <i>P</i>
#7	.76: management style <i>N</i>	.35: safety culture: handoffs and transitions <i>N</i>	.76: coping style: optimistic <i>N</i>	.72: adaptation <i>P</i>	.41: stage transition: contemplation to preparation <i>P</i>
#8	.75: management level <i>B</i>	.34: causes of transition from preparation to action stage <i>P</i>	.74: coping style: evasive <i>N</i>	.58: valence of adaptation <i>P</i>	.41: stage of change <i>P</i>
#9	.73: organizational culture & climate: management support <i>N</i>	.34: retired/not employed <i>N</i>	.73: coping skills <i>N</i>	.54: psychosocial adaptation: psychosocial distress <i>N</i>	.40: readiness to quit smoking <i>N</i>
#10	.73: time known by manager <i>B</i>	.34: transitional job stage [workers developing skills for unfamiliar tasks] <i>B</i>	.72: preoperative coping <i>N</i>	.54: psychosocial resilience <i>N</i>	.38: stages of change: contemplation <i>N</i>

Notes: Values reported in brackets are cosines between the retrieved term and the INN search term in the column heading. Letters after each search result indicate which literature the result was retrieved from: *B* = business administration, *E* = education, *P* = psychology, *N* = nursing.

Table 3

Comparison of INN Query Results to Concept Analysis Results

Related Terms from Concept Analysis	Number of INN Search Results Corresponding to Each Term				
	Self-Management	Transition	Coping	Adaptation	Readiness
A: Cognitive evaluation: awareness, knowledge, vulnerability	1	3	1	2	3
A: Coping style, optimism or pessimism	2	—	8	—	—
A: Emotional reaction to situation, burden of illness	—	2	1	1	1
A: Existing ecological system & resources available (personal, professional, social, educational)	10	10	—	12	7
A: Personal readiness for transition, knowledge, skills	6	5	1	7	31
A: Self-efficacy, health-related locus of control	1	1	1	2	—
A: Unstabilizing event	2	6	1	1	—
Att: Behaviors or actions	9	7	8	8	—
Att: Navigating systems (personal, social, healthcare)	2	—	—	1	—
Att: Phases of developing expertise and responsibility	—	3	—	—	4
Att: Response to situation: cognitive, emotional, values, motivation	6	—	19	8	2
C: Developmental process	—	1	—	1	—
C: Escaping from burden of illness	—	1	3	—	—
C: Hopefulness	—	—	—	—	—
C: Partnerships (health care providers, social support)	3	—	—	1	—
C: Sense of control	—	1	—	—	—
C: Stability of personhood	—	—	—	—	—
Other or No category	8	10	7	6	2

Note. A = antecedent, Att = attribute/aspect, C = consequence. Cells with no value indicate that no INN results were coded as belonging to that category.