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JO AZZARELLO
Norman, Oklahoma
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UMI Number: 9810309

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

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BY

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ABSTRACT

Previous research on problem solving has shown that possession of organized and interconnected knowledge structures appear to underlie superior problem representation ability. The majority of research on the relationship of structural knowledge and problem solving has concentrated on representation of problems that consist of a single problem entity. Many times, however, a problem situation actually consists of several concurrent and interacting problem entities, each requiring its own set of solutions. In addition, current research has not examined those cases where problem data indicate the potential for a problem to develop in which solvers are required to recognize the likelihood of a future problem. This study examined knowledge structures and problem representation in persons facing a complex problem situation that consists of coexisting multiple actual and potential problems.

To investigate the research questions posed by this study, a novice/expert comparison design was used. The problem solving domain of interest was home health care nursing, with five newly licensed RNs participating as novices and five RNs experienced in home care nursing participating as experts. Participants completed a written question-answering task to measure pertinent knowledge structures, read a patient scenario, and answered scenario-related questions while thinking aloud. The scenario described a patient who had multiple concurrent, interacting problems plus was likely to develop additional problems if no interventions were instituted.

The findings of the study provided evidence that experts' underlying knowledge structures were more accurate, extensive, and interconnected than the novices'. Also, experts' problem representations were more complete, complex, and cohesive than those of the novices, with experts demonstrating some superiority in recognizing potential problems as well. Weaker knowledge links in underlying structural knowledge appeared to be associated with lesser ability to draw appropriate inferences during problem representation. Experts also appeared to have more knowledge of conditions of applicability of underlying knowledge to the problem situation than did the novices. A moderate positive relationship was also found between interconnectivity of structural knowledge and cohesion of problem representation.

CHAPTER 1

INTRODUCTION

Researchers have investigated problem solving in such diverse domains as physics (Chi, Feltovich, & Glaser, 1981), computer programming (Anderson, Pirolli, & Farrell, 1988), and medical diagnosis (Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988; Patel & Groen, 1986). These researchers have learned much about the problem solving process, differences in problem solving skills of novices and experts in a specific domain, and, to some extent, how skill in problem solving is developed.

An important factor which appears to underlie experts' superior problem solving ability, particularly problem representation, is possession of an organized and interconnected knowledge base, also referred to as "structural knowledge" (Jonassen, Beissner, & Yacci, 1993). In contrast, novices' underlying knowledge structures tend to be characterized by weak, sparse, or poorly organized relationships among facts and concepts (Chi, Feltovich, & Glaser, 1981). Several studies indicate that domain specific problem solving relies on adequate structural knowledge of the concepts in the domain (Gordon & Gill, 1989; Robertson, 1990).

The majority of research on the relationship of structural knowledge and problem solving has concentrated on representation of problems that consist of a single problem entity. Many times, however, a problem situation actually consists of several concurrent and interacting problem entities, each requiring its own set of solutions. That is, within a given situation there is not just one problem to identify and solve, but many coexisting problems, some interacting with each other. In addition, current research has not examined those cases where problem data indicate the potential for a problem to develop, in which solvers are required to recognize the likelihood of a future problem. The interaction of multiple actual and potential problems can present a very complex problem solving task, particularly when actions indicated for one problem entity adversely impact on another coexisting problem. This study examined knowledge structures and problem representation for multiple actual and potential problems coexisting in a complex problem solving situation.

Purpose of the Study

Structural knowledge refers to the organization and strength of connections among concepts within a content domain. Problem solving refers to the ability to analyze data, work out a conceptualization of the problem, and propose a solution. Although it is generally accepted that an organized underlying knowledge base is necessary for adequate domain specific problem solving (Glaser, 1989), it remains unclear what the specific characteristics of underlying knowledge structures are that contribute to the ability to identify actual and potential problems in situations where there are multiple concurrent, interacting problem entities.

This study investigated and described similarities and differences between persons with varying levels of expertise in a domain regarding their (a) underlying structural knowledge of the domain, including the types of relationships connecting concepts within the domain, and (b) ability to represent problems consisting of several concurrent problem entities which are interacting, actual or potential. The association between how domain knowledge is structured, and subsequent problem representation within that domain was also examined.

Problem Solving Domain of Interest

Registered nurses (RNs) who practice in the specialty of home health care routinely face problem situations described above, where a patient often has multiple interacting medical, functional, or behavioral problems, both actual and potential, affecting health status. Home care nursing practice is directed toward achievement of goals related to restoration, rehabilitation, and palliative (hospice) care, and developing patient or caregiver competence and judgment in the independent management of health care needs at home (Rice & Smiley, 1992).

This focus requires the ability to recognize and manage a broad range of interacting factors that affect both the patient's current health status and potential threats to health, such as nutrition, mobility, and mental status, as well as physiological changes related to medical diagnoses. From the patient data available, the nurse must develop a conceptualization of the patient's condition and functioning that includes all actual or potential problems in order to develop the most comprehensive and effective treatment.

The comprehensive focus of home care nursing practice makes it an ideal domain in which to examine the relationship of knowledge structures and problem representation in situations where there are multiple interacting problem entities, both actual and potential.

Since extensive practice in a domain is a key factor in the development of expert problem solving abilities (Anderson, 1982; Tennyson & Rasch, 1988), it would be expected that underlying structural knowledge and problem representation skill in home health care nursing problems would differ between RNs who have had little professional nursing experience (recent graduates) and RNs with extensive home care experience (experts in the home care nursing domain). Therefore, novices and experts in home health care nursing are used as participants in this study.

Background

Previous research on problem solving has examined both generic problem solving and problem solving specific to a particular domain of knowledge. Generic problem solving is a generalized skill applicable in a variety of areas and does not require specialized content knowledge. The information processing studies of problem solving in the 1960s and 1970s identified the basic information processing capabilities people use when solving generic problems (Glaser, 1989). For example, Newell and

Simon (1972) described means-end analysis and subgoal decomposition, general processes used when solving problems that do not require an extensive knowledge base in any particular content area, like the Tower of Hanoi problem.

More recent research has focused attention on problem solving that requires a rich repertoire and structure of content knowledge, that is, "domain specific problem solving." This line of research has concentrated on describing the nature of problem solving cognitions related to specific content areas.

Domain specific problem solving is the process through which an individual selects relevant information from the problem statement or task instructions, makes inferences based on prior knowledge and experience with the problem domain, and integrates problem information with solution procedures (Hassebrock, Johnson, Bullemer, Fox, & Moller, 1993). The solver develops an internal model, or problem representation, that consists of elements within the problem, the relationships among them, and inferences drawn from the knowledge base of the solver (Greeno, 1977). Problem representation may thus be conceptualized as a semantic network of entities and the relationships among them (Greeno, 1977).

Problem representation is constructed by a solver on the basis of the individual's domain-related knowledge and its organization (Chi, Feltovich, & Glaser, 1981). An extensive and organized knowledge base supports development of a problem representation that is based on relevant, underlying principles, and solutions that are more likely to result in successful problem resolution. A less extensive or poorly organized knowledge base supports development of a problem representation that is superficial, incomplete, or inaccurate and is less likely to be linked to principles and procedures that lead to successful problem resolution.

A common approach in domain specific problem solving research has been the comparison of novices and experts on problem solving performance in particular fields, for example, physics (Anzai, 1991), chess (Charness, 1989), and medicine (Groen & Patel, 1991). From these studies, several characteristics of experts' problem representation have been identified that are robust and generalizable across domains. These include the findings that experts: (a) are able to avoid attention to the irrelevant details of problems in their domain, focusing instead on meaningful patterns in the information in the problem, and (b) are able to infer additional information for problem solving from available problem data.

Pattern Recognition. In building a problem representation, experts are able to recognize patterns in the data, avoiding attention to irrelevant details. Much of an expert's power lies in the ability to quickly establish correspondence between externally presented events and internal models for these events (Chi, Feltovich, & Glaser, 1981).

Ability to Make Inferences. Experts are also able to infer additional relations and constraints from the task situation, again reflecting the organization and extensiveness of the expert's knowledge base. Experts typically try to "understand" a problem by building a mental representation from which they can infer relations that can define the situation (Glaser & Chi, 1988). Experts' knowledge structures augment the information stated in a problem with associated information from the knowledge base.

Structural Knowledge. An interconnected, organized knowledge base appears to underlie experts' ability to detect relevant patterns in problem data, to infer additional relations and constraints from the task situation, and to arrive at problem solutions with greater speed and accuracy (Glaser, 1989). The organization and interconnections among declarative facts within the learner's knowledge network is referred to as "structural knowledge" (Diekhoff, 1983; Jonassen, Beissner, & Yacci, 1993; Tennyson & Rasch, 1988). Structural knowledge mediates the translation of declarative knowledge *(knowing that)* into procedural knowledge *(knowing how)* and facilitates the application of procedural knowledge (Jonassen, Beissner, & Yacci, 1993).

Lack of adequate structural knowledge may be one reason why novices are less likely to establish correspondence between externally presented events and internal models for these events, or to infer additional relations and constraints from the task situation. The novice's knowledge structures may be much less developed, with weaker or inaccurate associations between and among some elements than experts. Novices "do their best" with their limited understanding of the relationships among elements in the problem, but representations cannot include essential underlying principles if they simply are not there, or are not organized correctly within the network (Ericsson & Staszewski, 1989).

Problem Statement

Previous studies have been successful in identifying some aspects of knowledge structures and problem solving that differentiate novice and expert problem solvers. However, these characteristics have often been explored in separate studies, so that knowledge structures and problem representation were not examined within the same subjects. Other studies that did examine both of these characteristics within the same subjects used novice subjects only, so that no comparison could be made between novices and experts. Also, at times data were reduced to single indexes or scores (i.e., a problem was either correct or incorrect). Although a relationship between knowledge structures and problem solving could be determined, a qualitative examination and comparison of underlying knowledge or problem representation could not be made. These studies are discussed in detail in the next chapter.

Finally, little research has been conducted to describe the structural knowledge that underlies ability to represent problems for situations in which there are multiple interacting problem entities, both actual and potential. The present study begins to explore this area by describing the underlying knowledge structures of novices and experts in the domain of home health nursing, and their subsequent ability to recognize patterns in problem data and to make inferences for complex problem situations.

Significance of the Study

This study may contribute a greater understanding of knowledge organization and its contribution to the ability to recognize patterns in problem data and make inferences, in situations where problems contain multiple interacting actual and potential problem entities. Identification of underlying knowledge structures that contribute to expert performance in these problems can provide guidance to designers who develop problem solving instruction. Including instruction on the organization of underlying concepts and their relationships to each other, in addition to instruction on what concepts are necessary to know, would likely facilitate learners' ability to develop more complete problem representations, and consequently more accurate, comprehensive solutions.

Research Questions

1. What are the similarities and differences in underlying knowledge structures between novices and experts in home health care nursing?

2. What are the similarities and differences between novices and experts in home health care nursing in ability to recognize patterns in problem data and to make inferences for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

3. How does the organization of the underlying knowledge base relate to problem representation for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

CHAPTER 2

REVIEW OF THE LITERATURE

The purpose of this study is to investigate and describe similarities and differences between novices and experts in home health care nursing, comparing their underlying structural knowledge of the domain and ability to represent certain complex problem situations. These complex problem situations are those that consist of several concurrent problem entities which are interacting with each other. Some of the problem entities are actually occurring ones, while others have the potential to occur if no intervention is instituted. Also, investigated is how the organization of the underlying knowledge base contributes to the representation of these complex problem situations.

This chapter reviews what is known regarding similarities and differences between novices and experts in pattern recognition and inference making during problem representation and the relationship between problem representations and underlying knowledge structures. The chapter concludes with a review of the methods for assessing problem representations and underlying knowledge structures.

Novice and Expert Differences in Problem Representation

Research on novice and expert differences in problem solving has evolved from early studies of human information processing and general heuristic processes, to more recent research on the nature of problem solving related to specific content areas or domains. This evolution was spurred largely by developments in artificial intelligence (AI) and cognitive psychology (Glaser & Chi, 1988). In AI research, it was found that the identification of domain-independent heuristics to guide search through a problem space resulted in machines that could perform only intellectually trivial tasks. What was needed for approximation of human performance were search processes that engaged highly organized structures of specific knowledge. The resultant shift to a knowledge-based paradigm in AI science in the early 1970s led to an increased interest in research on novice and expert differences (Feignebaum, 1989).

Similarly, early studies of human information processing capabilities were conducted in relatively content-free areas, such as ability to solve the Tower of Hanoi problem (Newell & Simon, 1972). When investigations moved to problem solving in areas rich in content knowledge, differences in expert and novice problem solvers emerged. For example, de Groot (1966) found that expert and novice chess players could be distinguished by the expert's ability to correctly reproduce large patterns of chess positions after only a few seconds of viewing. The researcher believed that it was the grandmasters' enormous knowledge base containing thousands of familiar chess patterns, rather than superior information processing abilities, that accounted for their superior performance. Research in cognitive psychology continued to identify and explore additional novice and expert differences in the area of chess as well as other domains.

This research has revealed several characteristics of expert problem representation which are robust and generalizable across domains. These include the findings that experts: (a) are able to avoid attention to the irrelevant details of problems in their domain, focusing instead on meaningful patterns in the information in the problem, and (b) are able to infer additional information for problem solving from available problem data.

Pattern Recognition. The ability of experts to perceive large meaningful patterns in a problem situation was revealed in early studies of novice and expert differences in the area of chess play. In his attempt to discover what constituted skill in chess, de Groot (1966) noted that expertise was not reflected in the number of moves the players considered during search for a good move, in the number of moves ahead that were searched, nor in the search strategies used. De Groot did, however, find a distinguishing difference between the expert and novice chess players. He presented expert and novice players with chessboards that had pieces in a configuration that occurred in a game. The subjects were allowed to study the pieces for five seconds before the boards were removed. The chess masters were able to correctly reconstruct from memory the positions of 20 chess pieces or more, while novices could reconstruct only four or five. It appeared that the chess masters had built up more extensive memories for patterns of common board configurations than the novices.

Researchers continued to examine the nature of the patterns stored by novice and expert chess players (Charness, 1989; Chase & Simon, 1973). Attempts were made to identify the structure and size of the patterns in the knowledge base, which were referred to as "chunks." Chase and Simon (1973) used a reproduction task, where subjects were required to copy a chessboard configuration onto a blank chessboard, to examine the size of patterns stored by novices and experts. The subjects glanced at the target chessboard, placed some pieces on the test board, glanced back to the target chessboard, and placed more pieces on the test board, until they were finished. Head turns from board to board were used to segment the chunks. Both expert and novice players copied the placement of chess pieces pattern by pattern. The difference between the two was in the number of pieces contained in each pattern. The expert's patterns were larger, containing three to six pieces, and depicted meaningful relations among the pieces. The novice's patterns tended to contain single pieces.

Chase and Simon (1973) theorized that patterns of meaningful chess positions were stored in memory as closely knit units of knowledge structure, so that retrieval of one item of information within a chunk would lead to retrieval of another in quick succession. Experts, they reasoned, had stored a great many chunks consisting of relatively large patterns of meaningful chess positions. Thus experts would be able to quickly recognize pertinent patterns on the chessboard during play.

Studies of meaningful pattern recognition have been conducted in other domains as well, including such diverse areas as bridge (Charness, 1989), physics (Anzai & Yokoyama, 1984 ; Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982), and health care (Dempsey, Tucker, & Mullins, 1993; Gale & Marsden, 1983; Hassebrock, Johnson, Bullemer, Fox, & Moller, 1993; Kassirer & Gorry, 1985; Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988; Patel & Groen, 1986). Chi, Glaser, and Rees (1982) noted the finding from chess research that poor players were not as likely to detect meaningful patterns on the chessboard, and conducted a series of studies on physics problem solving in an effort to determine if there were parallels in the domain of physics. To identify how novices and experts differed in ability to identify relevant cues in physics problems, the researchers presented problems to two novice and two expert subjects and asked them to state what problem features led to their "basic approach" in developing a solution. The kinds of features mentioned as relevant by the novices were literal objects and terms in the problems, such as "friction" and "gravity." Features identified by the experts were characterized as descriptions of the states and conditions of the physical situation described by the problem. Because the features noted by experts were not explicitly stated in the problems, the researchers referred to them as second-order features.

The researchers were interested in determining if experts derived their second-order features from the same literal cues that novices attended to in the problems. In the final study of the series, six novices and six experts were asked to solve the same set of problems used in the earlier study, rate the difficulty of each problem, and circle the key words or phrases that helped them reach that judgment. A striking finding was the extensive overlap between the cues the experts and novices identified as important for deciding on the difficulty of the problem. For 19 of the 20 problems, the experts and novices circled the same sets of words or phrases in the problem statements.

The results suggested that novices' difficulties in problem solving did not stem from failure to identify relevant cues. The relevant key terms in the physics problems were identified by novices quite accurately. In this sense, a physics problem was not analogous to a "perceptual" chessboard, in which case novices could not pick out the relevant or important patterns. However, the similarity between chess experts and physics experts could be seen in their ability, compared to novices, to abstract the relevant underlying knowledge cued by the external stimuli. Novice chess players were just as capable as the experts of perceiving chess pieces per se, but the chess masters' expertise lay in the ability to impose a cognitive structure onto the patterns of chess pieces. The novice physicists were just as capable as the experts in identifying the key terms in a problem statement, but had limited ability to generate inferences and relations not explicitly stated in the problem (Chi, Glaser, & Rees, 1982).

Of particular interest to the present study is pattern recognition in health care problem solving situations. In general, findings from other domains have been supported by research in the medical fields. For example, Lesgold, Rubinson, Feltovich, Glaser, Klopfer, and Wang (1988) analyzed protocols of expert radiologists and medical residents who thought aloud while determining a diagnosis from examination of an x-ray film. Experts were able to interpret film features based on internal models of the patient's anatomy, and developed a more complete and accurate diagnosis. In contrast, residents interpreted their perceptions very literally. The novices built an internal, mental representation of the chest and its structures based on the literal manifestations of chest structures on the x-ray. To the novices, a heart shadow of large size meant an enlarged heart, which was incorrect.

The experts discounted many of the film's features that the residents thought were evidence of an enlarged heart by using a mix of technical knowledge about how x-ray films are made, better developed feature perception, and underlying knowledge of pathology. Experts tended not to mention heart size at all, and those who did attributed it to factors such as the patient not breathing deeply enough and a curvature in the spine rather than to an underlying disease state.

Unlike the novice physicists, the novice radiologists did not appear capable of picking out the relevant or important features of the problem at hand. However, the similarity between physics experts and radiology experts could be seen in their ability to abstract the relevant underlying knowledge cued by the external stimuli.

Lesgold et al., concluded that radiological diagnosis is a balance of recognition and inference that varies with experience. Viewed as a pattern recognition task, a radiologist detects some complex of features that can be mapped onto the name of a disease. From another point of view, radiological diagnosis is largely a matter of qualitative inference. That is, given a set of perceptual features or findings, the task is to determine which diseases are consistent with those findings.

In summary, research on pattern recognition indicates that experts are quite adept at focusing on meaningful patterns in the problem data. Experts' underlying domain knowledge apparently enables them to recognize and impart meaning to key elements in the problem, while avoiding attention to the irrelevant details of problem situation. This ability to recognize patterns is a prominent factor in the development of a problem representation.

The next section discusses the other characteristic of expert problem representation that has been identified: the ability to generate inferences from data given in problem situations.

Inference. As noted above, differences in novice and expert inference generation from problem data have been identified in the area of medical diagnosis (Groen & Patel, 1991; Lemieux & Bordage, 1992; Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988; Patel & Groen, 1991; Patel, Evans, & Groen, 1989; Patel, Evans, & Kaufman, 1990). The Lesgold et al., study found that radiologists were not only more likely to attend to relevant features of x-ray films than were novice residents, but the experts also demonstrated superior inference generation. The researchers analyzed protocols obtained from radiologists and residents who thought aloud while examining x-ray films. The number of findings, or specific properties of the film or patient, and the number of cause and effect reasoning steps stated in the protocols were then counted. The experts exceeded the novices on every measure ($p = 0.05$), having noted a greater number of findings, a greater number of cause and effect relationships among findings, longer reasoning chains, and a greater percentage of findings connected to at least one other finding. The researchers concluded that the data supported a view of the expert as doing more inferential thinking and ending up with a more coherent model of the patient shown in the film. In contrast, the novices' representations, as manifested in their protocols, were more superficial, fragmented, and piecemeal.

Similar findings were obtained by Patel, Evans, and Kaufman (1990), who examined diagnostic reasoning in medical students. Subjects were six students just entering their first year of medical school, six second year students who had completed all basic medical sciences but had no clinical work, and 12 final year students three months before graduation. The subjects were presented with a clinical case study and asked to provide a summary of the problem. Then, the subjects were asked to explain the underlying pathophysiology of the case study and to suggest a diagnosis. The explanation was constructed to justify the diagnosis and to explain the biomedical cues in the problem. Finally, the subjects were presented with excerpts from three basic science texts containing information related to the pathological events in the clinical case study, and an explanation of the clinical problem was asked for again. Subjects' comments were tape recorded for later analysis.

The propositional structure of subjects' protocols were represented as a semantic network consisting of nodes (facts given in the clinical case or drawn from basic science knowledge, and hypotheses about the case) and the relationships between nodes. During analysis, two dominant relationships between nodes were found: (a) the source node caused the target node, and (b) the source node was an indicator of the target node. An example of a causal relationship between nodes would be: POOR APPETITE causes MALNUTRITION. An example of an indicator relationship between nodes would be: EKG DATA indicates PERICARDIAL FLUID. Propositions in the explanation protocols were coded as originating from the clinical case study, basic science knowledge, or as unaccounted for.

After analyzing the subjects' initial diagnoses and explanations, the researchers found that final year students were able to infer an accurate diagnosis from the problem data and to provide extensive causal inferences among the clinical data and basic science knowledge in their explanations. Their protocols indicated an accurate understanding of the underlying disease process as it related to the case study data and the ability to infer relationships among all relevant clinical findings. First year students, in contrast, were unable to determine an accurate diagnosis and could offer only general explanations of the case. First year students' links between various findings in the case study were generated haphazardly and demonstrated lack of global coherence. Second year students focused on specific components of the disease processes from the case study and were able to provide a local coherence in the organization of groups of clinical cues. However, they were not able to infer connections among all of the relevant findings, and thus their protocols did not present a global understanding of the case study components as did the final year students'.

The subjects' second diagnostic explanations after reading the text information related to the pathological events in the clinical case study were then examined. The final year students had no change in diagnosis or in the selection of case study cues to confirm the diagnosis. They did, however, incorporate additional information from basic science in their explanations, thus providing a deeper account of the disease process. The first year students demonstrated an even further decrease in global coherence, although there was some improvement in local coherence. In general, the basic science information did not provide a context for deriving clinical inferences and did not in any way facilitate the process of making a diagnosis for first year students. Second year students actually demonstrated a decrease in global coherence, with explanations becoming fragmented into several components. Although the protocols, like those for the final year students, showed elaborated explanations between nodes linking concepts, more of the basic science inferences based on textual information were found to be inaccurate as compared to the final year students.

The researchers concluded that application of the basic science information was highly dependent on whether or not the individual already had a strong knowledge of classification of disease categories. The final year students had developed partial disease classifications through their clinical experience, and this assisted them in attending to relevant cues in the case study, in selecting an initial, accurate diagnosis, and in using basic science information to embellish their explanations. The second and first year students, who did not have a clinical basis for disease classification, were not able to use basic science knowledge to improve their explanations.

The researchers suggested that expertise requires the development of adequate knowledge structures consisting of macrostructure representations of disease classifications and the ability to distinguish between relevant and irrelevant information in the problem. These knowledge structures enable use of basic science information to infer a more global, cohesive understanding of disease processes during formation of a diagnosis.

The Patel, Evans, and Kaufman (1990) study reported general descriptions of findings from their study, implying a relationship between inference and diagnostic accuracy. A more direct examination of inference generation and accuracy of problem representation was included in the studies by Chi, Glaser, and Rees (1982). In the first of their studies, five physics problems were presented to two experts and two novices, who solved the problems while thinking aloud. Protocols were analyzed with particular attention to statements that seemed to generate knowledge not explicitly stated in the problem, i.e., inferences.

Novices as well as experts were found to spend time analyzing the problems qualitatively prior to solving them. During this stage, inferences about the problems were drawn. The researchers counted the number of propositions that were judged to be inferences, and found that the experts averaged 12.75 propositions and the novices averaged 10.58. The researchers noted that this could not be judged a reliable difference between the two groups.

The researchers then looked at the novices' solution errors and inferences. Of interest is that while novices' solution errors could at times be traced to trivial computational error, a significant source of errors was either the generation of wrong inferences or the failure to generate the right inference. Incorrect inferences were relatively easy to detect in the protocols. However, it was more difficult to detect the solver's failure to generate a necessary inference. The researchers could only capture failure to generate a necessary inference by comparing and contrasting the experts' and novices' protocols. Doing so revealed gaps in the novices' inference generation, as with one novice who failed to infer a relationship between friction and angle. Without relating these two problem features, as the expert did, the novice was unable to correctly solve the problem, even though he had noted all the necessary equations during the solution phase of the protocols.

The researchers concluded that, in general, both experts and novices were just as likely to spend time generating inferences. However, it was the quality of the inferences that mattered. Novices were more likely either to generate the wrong inference or to fail to generate the necessary inferences. A large number of the novices' errors could be attributed to this source.

In summary, it appears that problem representation requires both the recognition of relevant problem features and the use of inference based on what is found. The literature on problem representation suggests that recognition and inference are two principle factors that dominate experts' performance. However, these two factors are not independent. Efficient inference making during problem solving requires swift recognition of relevant factors in the problem, and recognition of relevant problem data requires appropriate inference. Anzai (1991) suggested that coordination between recognition and inference is one of the dominant process factors for expertise, and that both are influenced by the structure of domain specific knowledge.

Structural Knowledge and Problem Representation

Research on the problem solving ability of experts and novices has shown consistent findings across a variety of domains: the quality of the representation determines the quality of solution. The ability to recognize patterns in problem data and to generate inferences is clearly essential to the development of a complete and accurate problem representation. What is also apparent from the research is that underlying knowledge organization determines the quality, completeness, and coherence of the representation (Glaser, 1990).

What is less apparent, however, is the specific nature of the knowledge structures that underlie problem representations, particularly in complex problem solving situations. If the knowledge structures of experts are different from those of novices, in what ways are they different? How do the knowledge structures of novices and experts hinder or enhance development of a quality problem representation?

The most extensive work in identifying the nature of knowledge structures has been conducted in the field of physics (Chi, Glaser, & Rees, 1982; de Jong & Ferguson-Hessler, 1986; Robertson, 1990). The series of studies by Chi, Glaser, and Rees (1982) directly attempted to answer these questions. The researchers began by attempting to capture what subjects knew about physics independent of a problem-solving context. They adopted a simple approach of asking four experts (two college professors, one postdoctoral fellow, and one fifth year graduate student) and four novices (undergraduates who had just completed an introductory physics course with a B grade) to review a chapter from a physics textbook that introduced Newton's three laws (same textbook as used in the novices' physics course). Subjects were allowed 5 minutes to review the chapter, and then were to summarize out loud its important concepts. The book was available to the subjects while they summarized, so that any limitations in the summaries could not be attributed to a retrieval problem. Subjects were given 15 minutes to state their summaries.

The researchers found that experts in general made more complete statements about the laws than the novices did, even though the textbook was available for them to use. The experts also mentioned more subcomponents of the laws than the novices did. For example, experts mentioned an average of three subcomponents of Newton's First Law compared to an average of two subcomponents at most by the novices. The researchers were surprised that the novices did not perform better since they had already completed a course in which this information was taught, plus they had the book available.

The researchers concluded from this that novices lack a certain fundamental knowledge of physics principles. From other studies they also concluded that novices make errors in problem solving when they have either generated incorrect inferences or failed to generate the correct inferences during the problem representation stage. The researchers attributed generation of the wrong inference to incomplete knowledge, so that the appropriate inference (the right link between certain nodes in the semantic network) cannot be made. Finally, whether novices and experts have the same knowledge base or not, it is organized differently. That is, knowledge of problems for novices centers around objects, while knowledge of problems for experts centers around principles.

Noting that these deficiencies were rather general in the sense that the researchers did not have a good grasp of exactly what knowledge was missing from the novices' underlying structures, Chi, Glaser, and Rees (1982) conducted another study to identify specific knowledge associated with physics concepts. Two experts and two novices were presented with 20 prototypical physics concepts one at a time and were given 3 minutes per concept to tell everything they could think of about it and how a problem involving the concept might be solved. The protocols were analyzed as node-link networks, where the nodes were key terms mentioned by the subjects and the links were unlabeled relations that joined the concepts that were mentioned contiguously.

Data analysis indicated that the knowledge common to both novices and experts pertained to the concepts' physical configuration and properties, but that the experts had additional knowledge relevant to the solution principles based on major physics laws. For example, the researchers examined all statements made by the two experts and the two novices throughout the protocols of the entire set of 20 concepts and recorded all statements made about Conservation of Energy. Nearly half of the experts' statements (10 out of a total of 22 for one; 9 out of 21 for the other) were specifying the conditions under which Conservation of Energy could be used. The novices made only one such statement between them (1 out of 22 for one; 0 out of 13 for the other). Experts' mentioning of the conditions of applicability of Conservation of Energy pointed to the presence of not only explicit procedures in the experts' repertoires, but also of explicit conditions under which Conservation of Energy could be used.

This is the same conclusion that Glaser (1989) noted in his summary of novice and expert differences in problem solving. That is, experts know about the application of their knowledge, with declarative knowledge tightly bound to conditions and procedures for its use. A novice may have sufficient knowledge about a problem situation, but lack knowledge regarding the conditions of its applicability.

The excellent Chi, Glaser, and Rees (1982) studies were successful in identifying aspects of problem representation and underlying knowledge structures that differentiate novice and expert problem solvers. However, their method involved examining these characteristics separately from each other, so that knowledge structures were evaluated in isolation from ability to represent or solve problems. That is, there was no direct examination of knowledge structures and problem representation ability in the same subjects.

Also, although the researchers noted that pattern recognition and inference abilities appeared to be significant factors that differentiated novice and expert problem representation, their studies did not explore the specific contents of underlying knowledge that might be associated with these characteristics. For example, in the study of underlying knowledge structures where subjects were asked to tell everything they could about 20 physics concepts, the researchers analyzed the obtained protocols as node-link networks, but left the relations joining the concepts unlabeled. Therefore, it was not possible to examine specifically how concepts were associated in underlying knowledge, only that they were associated in some manner.

A later study of physics problem solving conducted by Robertson (1990) did examine knowledge structures and problem solving within the same subjects. Twenty physics students who were approximately two-thirds of the way through their first semester of a college physics course were presented with three problems involving Newton's Second Law and asked to think aloud while solving them. Obtained protocols were analyzed for statements indicating knowledge of concepts and their relationships in problems involving Newton's Second Law. The statements were coded and categorized as either positive (understand) indicators or negative (don't understand) indicators for solving problems involving the concept. From these codes, an "index of system-concept understanding" was assigned to each subject. The index was a numerical sum of positive and negative indicators for each problem.

One to three weeks later, the same subjects were given a written test containing three transfer problems. The transfer problems were structurally, but not conceptually, unfamiliar to the subjects. The correlation between the system-concept index and performance on the transfer test was .762 ($p < .001$), indicating a strong, positive relationship between concept related knowledge as measured during problem solving and ability to solve transfer problems. Other factors that were also examined for correlation with ability to solve transfer problems were ACT scores, course exam scores, sex of subject, and performance on familiar problems. None of these other factors were significantly associated with ability to solve transfer problems.

The Robertson study did provide additional evidence that an individual's underlying knowledge structures were associated with performance during problem solving by examining both characteristics within the same subjects. However, there were several limitations to the study. It involved examination of novice subjects only, so that no comparison could be made between the characteristics of both novices and experts. Also, the rich information obtained during the think-aloud was reduced to a single index of understanding, so that qualitative examination and comparisons of underlying knowledge could not be made. It was not possible to explore the concepts and their interrelationships from the data provided, which would have been helpful in examining the specific aspects of knowledge that were held by the subjects. Finally, the written transfer problems were scored as either correct or incorrect, so that explicit problem solving processes and sources of error could not be identified.

In summary, differences between novices and experts in both pattern recognition, inference, and underlying knowledge structures have been identified. Novices' underlying knowledge is less complete and contains more erroneous information than that of experts. Also, novices' knowledge tends to be organized around surface features of a problem rather than around principles. Experts' knowledge also appears to be bound to conditions of applicability. However, studies that directly explore the relationship between underlying knowledge structures and problem representation, especially within complex problems, have been limited. The present study examines in more detail the underlying knowledge structures of both novices and experts, and relates them to pattern recognition and inference during representation of complex problems.

Methods for Examining Knowledge Structure and Problem Representation

A variety of methods have been used by researchers to identify and explore underlying knowledge structures and problem representations. This section briefly reviews some of the common approaches, and then focuses in detail on those methods upon which the present study's methodology is based.

Review of Methods

Research on expertise has shown that experts have a large body of specific knowledge on which they draw to generate their performance. The major challenge for researchers is to elicit and describe the content and organization of that knowledge, as well as to identify how that knowledge is acted on to solve problems. Olson and Biolsi (1991) reviewed various techniques for representing expert knowledge and noted that methods can be classified as either indirect or direct.

Indirect methods generally require subjects to perform a variety of tasks, such as rating how similar two objects are or recalling a set of objects several times from several starting points. The researcher then infers underlying structure among the objects rated or recalled. Examples of indirect methods include multidimensional scaling, a technique that assumes underlying mental representations are analogous to physical dimensional spaces; hierarchical clustering, a technique that assumes that an item is or is not a member of a cluster whose items all belong to the same category; and general weighted networks (Pathfinder), a technique in which knowledge is conceptualized as a network of all objects interconnected through weighted links, and is based on spreading-activation theories of memory.

Direct methods elicit specific knowledge and strategies in the context of accomplishing particular tasks, from which the researcher identifies potential general characteristics of novices and experts. A common technique of these methods is the complex verbal protocol that is analyzed and represented as objects and their relationships. Examples of direct methods include open form (unstructured) interviews, question answering tasks, probes of explicit relationships, and think-aloud protocol analysis.

Question answering methods employing both written and think-aloud responses are used in the present study. The following section explains the basis for the question answering approach in representing knowledge structures and problem representation.

Basis of Methods Used in the Present Study

Question answering tasks allow specific information to be elicited by using questions of particular sorts. These questions may be either general or specific, depending on the information that is to be elicited. Patel and her colleagues used a question answering task in their studies of medical expertise (Groen & Patel, 1991; Patel, Evans, & Groen, 1989; Patel, Evans, & Kaufman, 1990; Patel & Groen, 1986; Patel & Groen, 1991). For example, Patel, Evans, and Kaufman (1990) presented novice and expert subjects with a medical case study and asked them to determine a diagnosis and to explain the underlying dynamics of the case. From protocols that were obtained, the researchers were able to identify concepts considered during subjects' arrival at a diagnosis, plus the relationships of the concepts to each other. The researchers then represented the concepts and relationships in a network or conceptual graph. Concepts were linked to other concepts by arrows indicating the direction of the relationship and were labeled with the type of relation noted by the subject. For example, one subject verbalized that the "patient" in the case study had a puncture wound on his arm, indicating that he had a drug abuse problem. The concept PUNCTURE WOUND was related to the concept DRUG ABUSE through the relationship "indicated." This process resulted in detailed semantic networks of concepts plus the specific relationships among them.

These networks or graphs can be considered analogous to the construct of problem representation (Feltovich & Patel, 1984). Chi, Glaser, and Rees (1982) define a problem representation as a cognitive structure corresponding to a problem, constructed by the solver on the basis of domain-related knowledge and its organization. A problem representation is the solver's internal model of the problem, its elements, relationships among them, and embellishments provided by the solver's knowledge. The networks of the Patel studies provide a method for representing the information in external events (a medical case study), the knowledge stored in subjects' memories, and the relations among elements that act on and modify these structures to produce inference (Feltovich & Patel, 1984).

The work of Patel has its roots in the area of discourse processing, the field that studies how people comprehend textual or spoken material. Comprehension is treated as a process of building an internal cognitive model of the message contained in verbal material. Construction of this model depends heavily on inference, the process of filling-in information not directly stated in the material, or giving interpretations to the text material depending on the individual's prior knowledge (Feltovich & Patel, 1984).

The approach taken in the Patel studies is particularly congruent with the present study's purpose of eliciting and representing the problem representations of novices and experts. However, while the Patel model is most useful in describing reasoning and representation during actual problem solving, it is inadequate as a method for examining the structure of domain knowledge that exists independent of a problem solving situation. That is, analysis of protocols obtained during problem solving tasks reveals only the underlying knowledge actually verbalized while solving a problem. It does not provide any information about other domain-related knowledge stored within the individual's memory but not activated or used during that particular task. Therefore, it is not possible to determine if failure to recognize patterns in the problem data or failure to generate inferences during problem representation reflect the absence of necessary underlying knowledge, or the inability to recall or apply the necessary knowledge even when it does reside in the individual's domain knowledge.

However, work within the field of discourse processing itself does offer methods for examining both problem representation (as in the Patel studies) and underlying knowledge structures. Graesser and Clark (1985) used question answering tasks in their extensive study of discourse processing and knowledge structures underlying text comprehension. The researchers hypothesized that during the course of reading written passages, a person successively builds up conceptual structures reflecting his or her comprehension of the passage. These structures consist of idea units explicitly contained in the passage, plus inferences which have been supplied by the person's generic knowledge structures. Generic knowledge structures are rich structures of knowledge that are activated when a concept or pattern in the passage matches or maps onto information in the person's long-term memory.

In the Graesser and Clark model, generic knowledge structures are conceptualized as a data base of general knowledge about concepts interrelated by links that capture the relationships existing between them. The researchers were interested in examining the generic knowledge structures related to key words in written passages, in an effort to better understand the process of inference during prose comprehension. To do so, they used a question answering task to elicit subjects' generic knowledge structures related to 51 concepts of interest. These concepts were selected from the passages that were used in a later part of the study.

Subjects were given booklets containing the concepts and were instructed to write down answers to a systematically generated set of questions for each concept. For example, for the concept DAUGHTER, subjects were asked "Why is a daughter female?" and "How is a daughter female?" The questions were used to elicit knowledge elements associated with the concepts through specific relationships. Examples of relationships are "property" and "cause." Property relations denote that content in one node is a feature, attribute, or characteristic of a second node. Cause relations denote that content in one node leads to, enables, or results in the content in the adjoining node.

The researchers were also interested in subjects' cognitive structures during passage comprehension. After the subjects had completed the task to elicit generic knowledge structures, they were presented with four passages one at a time. Subjects were presented with a set of questions after each of the four passages were read, such as "Why did X occur?" and "How did X occur?" Answers to these questions were represented as conceptual graphs consisting of a network of statement nodes, or basic idea units, which were interrelated by links that captured the relationships between the nodes. The type of links used in this part of the study were the same as in the previous part of the study. The conceptual graph structures were then analyzed on various dimensions, such as content and structure. For example, one structural measure was "structural centrality," the number of links radiating directly to or from the node.

Validity of the Question Answering Task for Problem Solving Research

Gordon and Gill (1989) believed that Graesser and Clark's question answering tasks and conceptual graphing techniques could be used in the study of knowledge structures in problem solving domains. They conducted a series of five studies with the primary goal of adapting the techniques used by Graesser and Clark to the study of problem solving. One question of interest was whether or not the use of question probes to assess structural knowledge would affect subsequent problem solving activity. That is, by thinking about and organizing answers to the questions, subjects might strengthen or reorganize knowledge structures in a way beneficial to accessing that knowledge for problem solving purposes.

The domain of interest in this study was engineering mechanics. Their subjects were sixty university students, divided into four groups. One group was given a set of question probes composed primarily of "what" and "why" questions related to basic concepts in mechanical engineering (ex., "what are the properties of __"). A second group was given a set of question probes composed of "how" questions (ex., "how do you _"). A third group was given both types of questions. A fourth group, the control, was not given any questions. After answers to the question probes were collected, the subjects were asked to solve four problems.

Problem solving scores were analyzed to determine whether question probes affected problem solving performance. Analysis of variance revealed no significant differences among the groups for any of the problems nor for subjects' total problem solving scores. The researchers concluded that using question probes to assess knowledge structures just prior to problem solving did not affect subsequent problem solving activity.

Because there was no evidence for question probe intrusiveness, additional analyses were performed for the data from subjects who had received both types of questions (group three). The researchers hypothesized that information obtained during the question answering task could be predictive of problem solving performance. Answers to the question probes were evaluated against a model procedural outline of the basic steps necessary to solve each problem. If information from the question probes matched the steps of the model, correct performance during the problem solving activity was predicted. If information from the question probes did not match the steps of the model (incorrect information or inadequate information), incorrect performance during the problem solving activity was predicted.

Information from subjects' question answers was compared to actual performance on the problems to see if the predictions were correct. Information from the questions was correct in predicting a majority (87%) of the steps used by subjects for solving each problem when compared to the model procedural outline. In addition, a strong correlation (.88) existed between the proportion of accuracy of subjects' answers to the question probes and the total problem solving score.

Question probe intrusiveness and prediction on problem solving performance were also examined in the domain of video recording, using identical procedures. Because of a low number of necessary steps in solving the video recording problems, intrusiveness was evaluated by combining points for all four problems for each subject. Mean scores were 12.8 for the group who received the question probes and 12.3 for the control group, a difference that was not statistically significant ($t < 1$). Predictive accuracy on problem solving was somewhat better for the engineering mechanics domain ($r = .88$) than for the video recording domain ($r = .82$).

The researchers were also interested in evaluating the degree to which information obtained using the question probes reflected the subjects' underlying cognitive structures. Recall clustering was used as an index of cognitive structure, since previous research had indicated that in free recall, subjects cluster or group words together on the basis of associations in memory (Gordon & Gill, 1989). Twelve subjects watched an instructional tape on video recording, were asked to recall the material, and then were administered question probes. Free recall protocols were transformed into propositional statements and compared to answers from the questions.

As the researchers expected, the information given in free recall was very limited relative to the information obtained from the question probes. Recall protocols averaged about 40 statements compared to the average of 223 propositions from the question answering task. In other words, the recall protocols reflected about 18% of what subjects knew about the topic as measured by the questioning answering task. Only two or three concepts per subject were verbalized in the free recall task that were not verbalized in the question answering task.

Statements verbalized in the free recall task were strongly clustered in the same manner as the concepts and relationships verbalized in the question answering task. The researchers concluded that answers from the question answering task did reflect underlying cognitive structures, since subjects' recall and question answers were so similarly clustered in the same manner.

The Gordon and Gill studies indicated there was no evidence that use of the question answering task changed subjects' problem solving behavior in either domain, and that data obtained from the question probes could be used as a means to predict performance on problem solving. The question answering task was also very useful for eliciting information contained in subjects' underlying cognitive structures.

Reliability and Validity of Verbal Protocols

Throughout investigations of knowledge structures and problem solving, researchers have made extensive use of methods for obtaining and analyzing verbal protocols, particularly through the think-aloud method (Chi, Glaser, & Rees, 1982; Gordon & Gill, 1989; Groen & Patel, 1991; Lemieux & Bordage, 1992; Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988; Patel, Evans, & Kaufman, 1990; Robertson, 1990). The think-aloud method is a type of verbal report in which an individual is asked to talk aloud while solving a problem or answering question probes. Verbal reports, or protocols, are recorded and later analyzed. The purpose of the think-aloud method is to obtain data about cognitive processes, most frequently the process of problem solving (Ericsson & Simon, 1993; van Someren, Barnard, & Sandberg, 1994).

Validity of the think-aloud method, that is, how well it reflects the cognitive processes of problem solving, rests on a set of assumptions about the general structure of the problem solving process, and about the verbal reporting process itself. Below are listed the major theoretical assumptions that underlie the think-aloud method.

1. During problem solving, information external to the individual flows from a sensory buffer into working memory (van Someren, Barnard, & Sandberg, 1994).

2. Information is also retrieved from the individual's long-term memory into working memory. The information continues to exist in long-term memory but is activated into working memory during the problem solving process (van Someren, Barnard, & Sandberg, 1994).

3. New information is constructed from incoming information and other information that is in working memory (Ericsson & Simon,1993; van Someren, Barnard, & Sandberg, 1994). Accumulated knowledge about the problem situation may or may not be correct.

4. New information in working memory may be stored in long-term memory (van Someren, Barnard, & Sandberg, 1994).

5. The individual puts into words some part of the information currently held in working memory (Ericsson & Simon,1993; van Someren, Barnard, & Sandberg, 1994). These verbalizations are the spoken protocol.

6. The information in working memory that is reported by the individual consists primarily of knowledge required as inputs to problem solving, the new knowledge produced, and active goals and subgoals (Ericsson & Simon, 1993).

The major threats to validity with the think-aloud method are incompleteness due to synchronization problems and invalidity due to problems with working memory (van Someren, Barnard, & Sandberg, 1994). The think-aloud method requires people to slow down their cognitive processes to synchronize them with verbalization. At times people report that verbalization does not keep up with the cognitive process, and that their verbal report is incomplete (van Someren, Barnard, & Sandberg, 1994). Therefore, protocols occasionally contain "holes" and it must be assumed that an intermediate thought occurred there.

Trials to determine final selection of methods for use in the present study were conducted using a written patient case study. Participants were asked to simply think aloud while discussing the case study. Analysis of the protocols obtained during the trials showed that often participants did not verbalize certain information that was of critical importance to the present study, such as whether or not they recognized a causal relationship between concepts in the case study. It was unknown whether participants did not have this information in working memory, or if it was simply not verbalized. Thus it was determined that a question answering version of the think-aloud technique would be used to probe for specific information that was of particular interest to the study. Results of pilot testing are presented in Appendix A.

The use of questioning, however, does introduce an additional threat to validity of the think-aloud method: disturbance of the cognitive process. There is the possibility that thought processes may take directions different from those they would have taken had the participants been left on their own (van Someren, Barnard, & Sandberg, 1994). However, since the nonverbalized information was central to the purposes of this study, the question answering method was used and data interpreted accordingly.

Finally, it is recognized in the literature that verbalization may place additional demands on working memory. However, for the present study it is felt that this will not pose a serious threat and the cost is expected to be acceptable.

CHAPTER 3

RESEARCH METHODOLOGY AND PROCEDURES

Research Questions

1. What are the similarities and differences in underlying knowledge structures between novices and experts in home health care nursing?

2. What are the similarities and differences between novices and experts in home health care nursing in ability to recognize patterns in problem data and to make inferences for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

3. How does the organization of the underlying knowledge base relate to problem representation for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

Research Design

This exploratory study used a novice/expert comparison design to examine similarities and differences between novices and experts, as well as the relationship between knowledge structures and problem solving ability.

Problem Solving Situation of Interest in the Study

Problem solving in any domain requires not only the ability to recall relevant facts and concepts, but to recall and apply relevant relational and procedural rules to those concepts (de Jong & Ferguson-Hessler, 1986). It is this ability to apply relational and procedural rules that may be the most critical factor in skilled problem solving (Gagné, 1985). Of interest in the present study are the organization of underlying concepts and the ability to select and apply appropriate relational rules when forming a problem representation for a complex problem solving situation.

Funke (1991) characterizes a complex problem solving situation as one with the following features.

1. Limited availability of information about the problem. In complex problem solving situations, only some variables (e.g., symptoms) lend themselves to direct observation. From these variables, the solver must infer the underlying state.

2. Multiple subproblems and related goals, some of which may be contradictory. Frequently, complex problem solving situations are characterized by the presence of not one, but multiple problems. Difficulties can arise when some of the goals and interventions for these problems are contradictory.

3. Connectivity of variables. A high degree of connectivity describes a situation in which changes in one problem variable can affect the status of other, related variables. Complex problems often contain a high degree of connectivity.

The problem situation in this study is one that is complex, in which the solver is presented with multiple "patient" symptoms and must infer several underlying, interconnected subproblems. The state of the various problem entities may have an influence on the state of the others, so that the existence of, or a change in, one may result in the existence of, or a change in, the other.

In addition, the problem entities exist as a mixture of actually occurring (active) problems that require intervention by the solver, and as a problem entity that merely has the potential to develop. The potential problem requires intervention by the solver in order to prevent it from developing into an active problem.

<u>Domain of Home Care Nursing</u>

There are hundreds of concepts relevant to the domain of home health care nursing, such as medication management, nutrition, skin integrity, safety, etc. Since only a limited number of concepts could be used in order for the study to manageable, a set of concepts was chosen based on congruence with the purposes of the study. In addition to their relevance to home care nursing, the study concepts must each meet the requirements of the problem situation as described above. That is, each must be capable of being represented as a problem that needs to be addressed, be able to exist concurrently within a single patient, and have a high degree of interrelationship among each other. Also, at least one of the concepts must be able to exist as a potential problem, rather than as one that has already occurred.

For the purposes of this study, the concepts of congestive heart failure, depression, impaired mobility, poor medication management, falls, and poor nutrition/hydration status were used. All may exist concurrently within a single patient, and may be interrelated. For example, congestive heart failure or impaired mobility could lead to depression. Also, a person could be at high risk for falling if appropriate interventions are not made, yet not have fallen yet. These six concepts were used in measures of both structural knowledge and problem representation.

Participants

Purposive sampling was used to select participants most representative of novice and expert levels of problem solving ability in home health care nursing, in order to enhance the identification of differences between the two levels of expertise. Participants were chosen so that both novice and expert individuals could be assumed to possess knowledge and understanding of concepts within the domain, yet differ in their amount of home care experience. It was assumed that those with more problem solving experience in home care nursing (experts) had developed more extensive, organized interconnections among concepts, as well as superior domain specific problem solving abilities, than novices with limited or no experience. A total of ten participated in the study: five novices and five experts.

Criteria for novices were:

a. Graduate from a baccalaureate program for registered professional nurses (RN).

b. No more than 6 months experience as a nurse.

c. No prior work experience in a home health care setting.

These criteria provided reasonable assurance that novice participants already had similar basic knowledge of the nursing concepts of interest, had similar student clinical experiences in home health care, plus ensured that participants did not have extensive opportunities to solve related problems.

Experts were RNs who met at least one of the following criteria:

a. Minimum of five years of experience in home health nursing, and whose peers or supervisors state have demonstrated superior knowledge and skill in home health nursing practice. See Appendix B for the types of questions used in evaluation.

b. Graduate degree in home health nursing or community health with an emphasis on home health nursing, at least three years experience in home health nursing practice, and whose peers or supervisors state have demonstrated superior knowledge and skill in home health nursing practice.

c. National certification by the American Nurses Association in home health nursing, at least three years experience in home health nursing practice, and whose peers or supervisors state have demonstrated superior knowledge and skill in home health nursing practice.

These criteria provided reasonable assurance that expert participants possessed well developed structural knowledge related to the concepts of interest, plus had extensive prior opportunities to solve home health care related problems.

Novices. Names and addresses of potential novice participants were obtained from the Oklahoma State Board of Nursing (OSBN). A list of 129 BSN graduate RNs who tested for licensure during the months of May and June, 1997, was generated by the OSBNR. The researcher contacted persons from the list who resided within reasonable driving distance and for whom telephone numbers could be ascertained. The researcher briefly explained the study, verified criteria for inclusion, and requested participation.

Four persons contacted were not eligible due to extensive prior experience as a licensed practical nurse or prior experience in home health care.

Five persons who met the criteria agreed to participate. Of these novices, four were female and one was male. Length of experience as an RN ranged from 2 weeks to 1 month.

Experts. Names of potential expert participants were obtained through personal contacts and recommendations from the Oklahoma Association for Home Care. The researcher briefly explained the study, verified criteria for inclusion, and requested participation.

Five persons who met the criteria agreed to participate. Of these experts, all were female. Length of experience as an RN ranged from 6 to 24 years. Home care experience ranged from 5 to 13 years. Two expert participants had a master's degree in nursing: clinical nurse specialist/education and family nurse clinician. Another expert was certified in home care nursing through the American Nurses Association. All were highly rated by supervisors or peers as having superior knowledge and skill in home care nursing.

The investigator arranged to meet with the volunteers one at a time. After obtaining informed consent, the exercises were presented and data collected in the order described below.

Measures

The measures used in this study are an adaptation of the techniques developed by Graesser and Clark (1985) in their studies of knowledge structures and discourse processing and Patel, Evans, and Kaufman (1990) in their study of medical problem solving. One measure assessed participants' general domain specific knowledge structures related to the six home care nursing concepts using a written question answering task. The second measure assessed participants' problem representation when the six home care nursing concepts were used in a complex problem situation using a think-aloud question answering task. Problem representation was analyzed using conceptual graph structures to model recognition of patterns in problem data and inference generation in a combined adaptation of techniques used by Graesser and Clark (1985) and Patel and Groen (1991).

Knowledge Structures

Structural knowledge refers to the organization and interrelationships among domain related concepts within an individual's knowledge base. There are two types of relationships or links among domain specific concepts that were of particular interest to problem representation in the present study. One is that which indicates the content in one node is a feature, attribute, or characteristic of content in a second node. This is referred to as a "characteristic of" link.

The other type of relationship is that which indicates a causal relationship between nodes, and is referred to as a "leads to" link. It should be noted that individuals usually do not store ideal representations of causal mechanisms, but rather only fragments of the true cause-oriented mechanisms (Graesser & Clark, 1985). Therefore, the "leads to" link does not indicate a strict causal relationship in the sense that one set of events or states constitutes a necessary and sufficient cause of another event or state. The "leads to" link is used in a more general sense to indicate that the content in one node leads to, causes, precedes, or results in the content of a second node.

"Characteristic of" and "leads to" relational links among domain specific concepts are of particular concern in the present study because they appear to be highly relevant to the conceptualization of problems in health care. In studies of problem solving that involve medical patients, representations are based on the domain-specific knowledge evoked in response to a specific set of symptoms and clinical findings in the case information. The types of medical and case information that have been found to be most relevant are interpretations of data characterizing the patient's condition and inferences of underlying causal dynamics (Broderick & Ammentorp, 1979; Groen & Patel, 1991; Hassebrock, Johnson, Bullemer, Fox, & Moller, 1993; Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988; Patel, Evans, & Kaufman, 1990; Westfall, Tanner, Putzier, & Padrick, 1986; White, Mativio, Kobert, & Engberg, 1992).

Therefore, knowledge regarding the characteristics of patients with health problems, as well as the causal factors or the likely outcomes of those health problems, appear to underlie the ability to recognize patterns in the problem data, to discern between relevant and irrelevant data, and to infer a more complete conceptualization of the problem. In the present study, characteristic and causal relationships associated with the study's primary concepts constitute participants' structural knowledge related to problem representation in home care nursing.

Question Answering Task: Knowledge Structures

A written question answering task similar to that used by Graesser and Clark (1985) was used to measure participants' structural knowledge. See Appendix C for this exercise. The purpose of this exercise was to identify concepts that participants linked to the study's primary concepts (congestive heart failure, depression, impaired mobility, poor medication management, falls, and poor nutrition/hydration status) in a "characteristic of" relationship (concept is a characteristic or attribute of the other), or in a causal relationship (concept leads to, causes, precedes, or results in a second concept). Causal relationships are of particular interest, since the identification of potential problems appears to be dependent on causal reasoning.

Information obtained in this exercise was used to answer the first research question: What are the similarities and differences in underlying knowledge structures between novices and experts in home health care nursing?

Participants were presented with each of the primary concepts printed at the top of a page, and asked to write their answers to two questions related to those concepts:

1. What characteristics might patients exhibit that would indicate they have a problem with [primary concept]?

2. What are the causes of [primary concept]?

Participants were given an opportunity to practice this exercise with a concept relevant to home care nursing, but not included in the study, prior to completing the exercise. There was no time limit for completion.

Question Answering Task: Data Analysis. Participants' written responses were analyzed according to the classification systems described below. These classifications and scoring rules were adapted from those used by Graesser and Clark (1985). Analysis was conducted by two persons knowledgeable and experienced in home health care nursing. Each rater was trained in the rating procedures, and interrater agreements of 91% and 97% were obtained on two practice sets of recalls.

Classification of each statement must have been agreed upon by the raters in order to be categorized. Final classification of statements in cases of disagreement were determined by the researcher.

The following are the classification systems and scoring rules for data obtained during the Question Answering Task.

1. Number of Statements in Response to Questions. The total number of statements by each subject in response to the two questions were determined and listed.

Rule 1a: Words or phrases separated by a comma, period, semicolon, or other common notation that indicates a listing were considered as separate, individual responses. Words or phrases separated by "and," "or," or other conjunctions were considered as separate, individual responses.

Rule 1b: A descriptor that applied to each word or phrase in a list following it was included with that word or phrase when it was listed as a separate response.

For example, in response to the question "What characteristics might patients exhibit that would indicate they have a problem with poor medication management?" a participant may write "incorrect time, dose, manner, or frequency." This response would be rated as four separate statements: incorrect time, incorrect dose, incorrect manner, and incorrect frequency.

Rule 1c: Responses may be given that represent a category or class of answers, and subsequently be followed by several examples of that class. In this case, the response would be rated as one statement (the category or class).

For example, in response to the question "What are the causes of impaired mobility?" a participant may write "debilitating illness (ex., MS, MD, etc.)." This response would be rated as one statement: debilitating illness.

2. Correct versus Incorrect "Characteristic of" Statements. The statements each participant had indicated per concept in response to the question "What characteristics might patients exhibit that would indicate they have a problem with [primary concept]?" were analyzed to see if they did or did not relate to the concept in a "characteristic of" manner.

Rule 2a: A statement was considered to be characteristic of the primary concept if it intended to describe a feature, attribute, or characteristic of a patient with a problem related to the concept. A "characteristic of" statement may be a sign, symptom, or situation of patients who experience problems related to the primary concept, including objective observations that could be determined by physical assessment or laboratory tests, subjective information that could be obtained through questioning, or social or environmental situations that could be assessed through observation or questioning.

Characteristic statements indicate that the primary concept exists. In other words, patients would exhibit a certain characteristic due to a problem with the primary concept.

Rule 2b: The "characteristic of" statements were categorized as either accurate or inaccurate.

For example, in response to the question "What characteristics might patients exhibit that would indicate they have a problem with poor nutrition/hydration?" a participant may write "poor skin turgor." This response is an objective observation that does reflect poor nutrition/hydration status. A patient may exhibit poor skin turgor due to poor nutrition/ hydration status so this statement would be scored as a correct "characteristic of" statement.

The statement "cyanosis," however, would not be characteristic of patients with poor nutrition/hydration status. That is, a patient would not exhibit cyanosis due to poor nutrition/hydration status so that statement would be scored as an incorrect "characteristic of" statement.

3. Correct versus Incorrect Causal Statements. The statements each participant has indicated per primary concept in response to the question "What are the causes of [primary concept]?" were analyzed to see if they did or did not relate to the primary concept in a "leads to" manner.

Rule 3a: A statement was considered to be a cause of the primary concept if the stated concept was intended to cause, lead to, enable, or result in the primary concept.

Rule 3b: The chronology of the event sequence must be such that the stated concept must occur or exist prior to the primary concept. For example, the concept "recent loss" would exist prior to the primary concept "depression," whereas depression would not exist prior to a recent loss.

Rule 3c: The statement must pass a "because" test: It makes more sense to say "primary concept occurs because of statement" than to say "statement occurs because of primary concept."

Rule 3d: The causal statements were categorized as either accurate or inaccurate. The number of statements that passed the first three rules and correctly described a causal relationship between the concepts were totaled as accurate "leads to" statements. Those that did not pass one or more of the first three rules and were inaccurate were counted as errors.

4. Interconnectivity Among Primary Concepts. Participants' statements related to each primary concept were examined for interconnectivity with the other primary concepts.

Rule 4: A connection between two primary concepts was considered to exist if a characteristic or cause statement for one primary concept: (1) was listed as a characteristic or cause of another primary concept (either identically or paraphrased with a similar meaning), or (2) was another primary concept. The connecting statements did not have to be of the same type for each primary concept. That is, a statement listed as a characteristic of one primary concept may also be listed as a cause of a second primary concept.

For example, "impaired mobility" may be listed as a cause of depression. "Depression" is also another of the primary concepts. This is an instance of interconnectivity between the primary concepts "impaired mobility" and "depression."

Rule 4a: The number of interconnections for a participant was the sum of all interconnections noted during the question answering task.

Rule 4b: The percentage of interconnections for a participant was the number of interconnections divided by the number of statements obtained during the question answering task.

Question Answering Task: Predictions Regarding Knowledge Structures. Based on what is known from previous research regarding novice and expert differences in domain knowledge, several predictions of the outcomes of the question answering task were made. It was expected that experts would be able to recall a greater number of concepts that correctly related to the primary concepts in both a characteristic or causal fashion than would the novices, since recognition of problems requires knowledge of their characteristics and causes. Recognition of potential problems requires knowledge of related casual factors in particular, since persons would not exhibit characteristics associated with a problem when it has not developed yet. Also, it was expected that experts' underlying knowledge structures would be more interrelated than those of novices.

The next section describes a think-aloud question answering task, designed to elicit problem representations of the participants using the same six primary concepts in a complex problem solving situation.

Problem Representation Ability

Problem representation refers to the ability to analyze data in a problem situation and work out a conceptualization of the problem. Of interest to the present study is participants' ability to recognize patterns in the data and to make inferences when presented with a patient scenario in which there are multiple interacting problems or potential problems.

The same six concepts used to measure participants' structural knowledge were used in the exercise to measure problem representation ability. In the problem representation exercise, however, the concepts were used within the context of a realistic patient scenario.

Think-Aloud: Problem Representation. Problem representation ability was measured using a think-aloud question answering task similar to that used by Patel, Evans, and Kaufman (1990). See Appendix D for this exercise. Problem representation includes participants' abilities to recognize patterns in a written patient scenario that contains both relevant and irrelevant data and to make inferences.

Information obtained in this exercise was used to answer the second research question: What are the similarities and differences between novices and experts in home health care nursing in ability to represent problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

Participants were presented with the patient scenario and asked to read it. Participants were allowed to study the scenario for three minutes and were not be allowed to refer back to the printed problem during the exercise. It was expected that inability to refer back to the scenario would force increased reliance on underlying knowledge structures during the formation of a problem representation and enhance expert and novices differences in the representation process.

After the participants read the scenario, they were instructed to write what problems they felt should be addressed by the home care nurse. Specifying the "patient's" problem areas required participants to determine which data in the scenario were relevant, to identify patterns, and to make inferences using the given data.

If participants did not mention any potential problems in their problem lists, an additional question was asked: "Are there any other problems you feel might occur if no interventions are instituted?" If the participants identify no additional problems, data collection proceeded.

After completing the list, each participant was asked to answer aloud questions designed to identify the specific scenario data that was used in problem inference and the relationships among concepts that were identified by the participants. When answering the questions, participants were instructed to say aloud everything they were thinking. Participants' discussions were tape recorded for later analysis.

Questions focused primarily on identifying the characteristic and causal relational links associated with the problems or potential problems participants identified. As noted earlier, these relationships appear to be highly relevant in the conceptualization of problems in health care. For each problem identified, participants were asked "How do you know she has a problem with [stated problem]?" and "What do you think is causing the problem with [stated problem]?" The first question was intended to identify "characteristic of" relationships associated with the stated problem. The second question was intended to identify causal relationships associated with the stated problem. The problems identified and the answers to these questions constituted participants' problem representation.

Think-Aloud: Patient Scenario. Recall that the problem situation of interest in this study is one that is complex, consisting of several concurrent and interacting problem entities within a single situation. The problem entities must exist as either actually occurring problems or as one with the potential to develop if no preventive intervention occurs.

The patient scenario used in the think-aloud task consists of information describing a single "patient" with problems related to the six primary concepts (congestive heart failure, depression, impaired mobility, poor medication management, falls, and poor nutrition/ hydration status). Scenario data include facts that are characteristic of the concepts and which imply a causal relationship among several concepts. History of one problem concept, congestive heart failure, is explicitly stated in the data. All other problem concepts and the relationships among them are not explicitly stated, but can be inferred from the given information.

Although facts are explicitly given that are characteristic of current problems with depression, impaired mobility, poor medication management, and poor nutrition/hydration status, no facts are given that indicate a problem with falls has occurred yet. In other words, there are no facts to imply that the "patient" has actually incurred a fall, but her situation is such that without appropriate intervention, a fall is likely to happen. This inference can be made by noting the causal relationships of poor medication management, decreased mobility, and living situation combined, which imply a potential risk for falls.

Also, there are no facts given that indicate the "patient" is having a current exacerbation of her CHF. However, there is the risk of an exacerbation of CHF occurring in the future, based on inferences that can be made from the problem data. The "patient" demonstrates poor medication management, which could lead to an exacerbation of CHF if medications taken to control that disorder are not taken as prescribed. Also, increasing fluid intake is an intervention that is indicated for treatment of another problem, dehydration. If fluids are increased too much, or too rapidly, the "patient's" CHF may exacerbate, especially if her medications are not being taken properly.

The scenario contains information that describes the "patient's" name, age, living environment, brief medical history, vital signs, medications, etc. Patient information is arranged so that facts related to the primary concepts are dispersed throughout the scenario. By not clustering pertinent facts together, participants were challenged to draw on their underlying knowledge structures to recognize patterns and work out a conceptualization of the problem.

Following is the patient scenario used in the problem representation task.

> You are a home health care nurse making a late afternoon visit to Mrs. Edna Murray, a 69 year old thin, slightly hard-of-hearing, white female with a history of CHF. She was discharged from the hospital two weeks ago after her most recent exacerbation of CHF. Mrs. Murray, a widow, lives alone in a two story brick home in the suburb of a large midwestern city. Mrs. Murray's only child, a daughter, lives out of state and has left a week ago to return to her own home after helping Mrs. Murray get settled after leaving the hospital. Mrs. Murray's home is clean although somewhat cluttered with books, magazines, collectables, and mementos on countertops and tables. Mrs. Murray, a former cook for a local "4 Star" restaurant, is sitting on the living room sofa. She is 5 feet 3 inches tall, and weighs 98 pounds. Her facial expression is blank, and she does not smile when speaking with you. Her oral temperature is 99 degrees Fahrenheit, radial pulse is 68 beats per minute, and respirations are 20 per minute with an occasional nonproductive cough. Her blood pressure is 122/64. You ask Mrs. Murray how she has been sleeping. Speaking in a slow,

monotonous tone, she tells you she has been sleeping about 5 hours at night, with frequent wakenings. Mrs. Murray has not taken her medications yet, so you check her medication sheet and find that she is taking furosemide (Lasix) 20 mg po Q am, digoxin (Lanoxin) 0.25 mg po Q am, and potassium chloride 20 mEq po Q am. You locate the medications in an upstairs bedroom. You find a clean glass in the kitchen next to a bowl of fresh fruits, find orange juice in the refrigerator behind a package of uncooked chicken, and help Mrs. Murray take her medications. Her skin is warm, dry, and flaky. It remains tented more than 5 seconds after it is pinched. Lung sounds are low pitched and soft throughout all lung fields. Her extremities have full ROM and moderate muscle strength. You notice she uses the support of walls and furniture when ambulating, and her gait is slow.

Think-Aloud: Data Analysis. Transcription, segmentation, and analysis of verbal protocols were completed by the researcher. Participants' responses were analyzed in a manner similar to that used by Patel, Evans, and Kaufman (1990) in their study. First, the data was translated into a conceptual graph structure, consisting of nodes interrelated by a network of directed relational links. The conceptual graph structures model participants' problem representation, including pattern recognition and inference generation. Then, participants' pattern recognition and inference generation were analyzed on various dimensions.

The following are the classification systems and scoring rules for data obtained during the problem representation task, adapted from Graesser and Clark (1985).

1. Conceptual Graph Structure. A conceptual graph structure is a set of statement nodes which are interrelated by a network of directed relational links (Graesser & Clark, 1985). A node is an idea or concept specified by the participants in the think-aloud exercise. Nodes may be either facts given in the patient scenario or inferences about the scenario.

Relational links represent the relationships between nodes and are directional. That is, a relational link connects two nodes, one of which is a source node and the other an end node. Classification of relational links among concepts are adapted from those used by Graesser and Clark, and focus on those that are "characteristic of" and "leads to."

Rule 1: Ideas or concepts identified by participants were entered in the structure as nodes.

Rule 1a: Participant statements that were identical to or paraphrased from facts in the patient scenario were entered in the graph structure and surrounded by a box.

Rule 1b: Statements that were inferences made from the scenario data were entered in the graph structure and surrounded by an oval. These facts and inferences form the nodes of the graph structure.

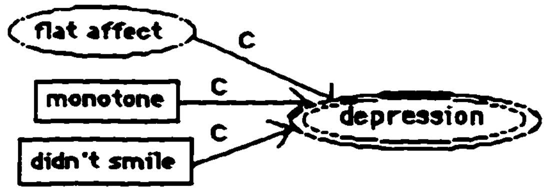
Rule 1c: Concepts listed as patient problems were surrounded by a double box if identical to or paraphrased from the scenario, or by a double oval if inferred. These were the problems noted by participants when asked to write what problems they felt should be addressed by the home care nurse.

Rule 2: Relationships between nodes were noted by connecting them with an arrow indicating the direction and type of relationship. "Characteristic of" and causal relationships are the same as defined in the earlier section on data analysis for measuring knowledge structures.

Rule 2a: Answers to the question "How do you know she has a problem with [stated problem]?" that met the definition of a characteristic link were connected to the related problem node with an arrow labeled "C" (characteristic of). The answer to the question was the source node, and the problem concept was the end node.

For example, a participant might identify depression as a problem, and state "flat affect, was monotone, didn't smile so could be depression" in response to the question "How do you know she has a problem with depression?" This would be graphed as shown below, with "depression" surrounded by a double oval (inferred and listed as a patient problem), "flat affect" surrounded by an oval (inferred from the data), "monotone" and "didn't smile" surrounded by a box (paraphrased from the data), and

"C" indicating a "characteristic of" link.



Rule 2b: Answers to the question "What do you think is causing the problem with [stated problem]?" that met the definition of a causal link were connected to the related problem node with an arrow labeled "L" (leads to). The answer to the question was the source node, and the problem concept was the end node.

Rule 2c: If participants' answers to the questions indicate that they were not sure of their stated answer, a question mark was placed before the questionable response on the graph. Clues that the participant was unsure but was offering a hypothesis or possibility to consider is the use of words or phrases such as "maybe," "possibly," or other similar phrase. This rule applied to nodes (both problem statements and answers to questions) and to relational links.

For example, if a participant wrote that one of the "patient's" problems is "incorrect medications," the node would read "incorrect medications." However, if the participant had written that one of the "patient's" problems is "possibly incorrect medications," the node would read "? incorrect medications."

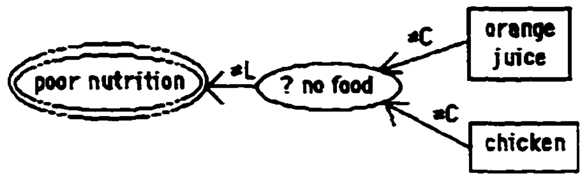
Rule 2d: Statements may indicate that two or more concepts or ideas are considered together in relationship to another concept. In this situation, all of the clustered concepts were surrounded by a solid line, with the relationship indicated in the usual manner.

For example, the fact that a patient lives in a two story home by itself would not normally be considered as posing a significant risk for falling. However, living in a two story home and poor mobility, when considered together, would be considered as high risk for leading to a fall.

Rule 2e: Some statements may indicated that information in one node is not supportive of a characteristic or causal relationship with a second node. In this situation, relationships were noted with "≠C" or "≠L" to indicate that information in one node is not characteristic or does not lead to the second node.

For example, a participant might note that the "patient" has a problem with poor nutrition, and answer the question on causation with this statement: "Maybe the woman doesn't have any food. But it said she has orange juice made up, and some chicken, so that wouldn't be it."

In this case, the conceptual graph would look like the following:



Rule 2f: If participants' answers did not meet the definition of characteristic or causal links, or are such that relational links cannot be clearly identified, a link (directional or nondirectional) was used and left unlabeled.

Rule 3: Errors in participants' problem representation were noted on the conceptual graph structures by placing an asterisk (*) beside the erroneous node or link. Errors may occur in recall, inference, or problem identification.

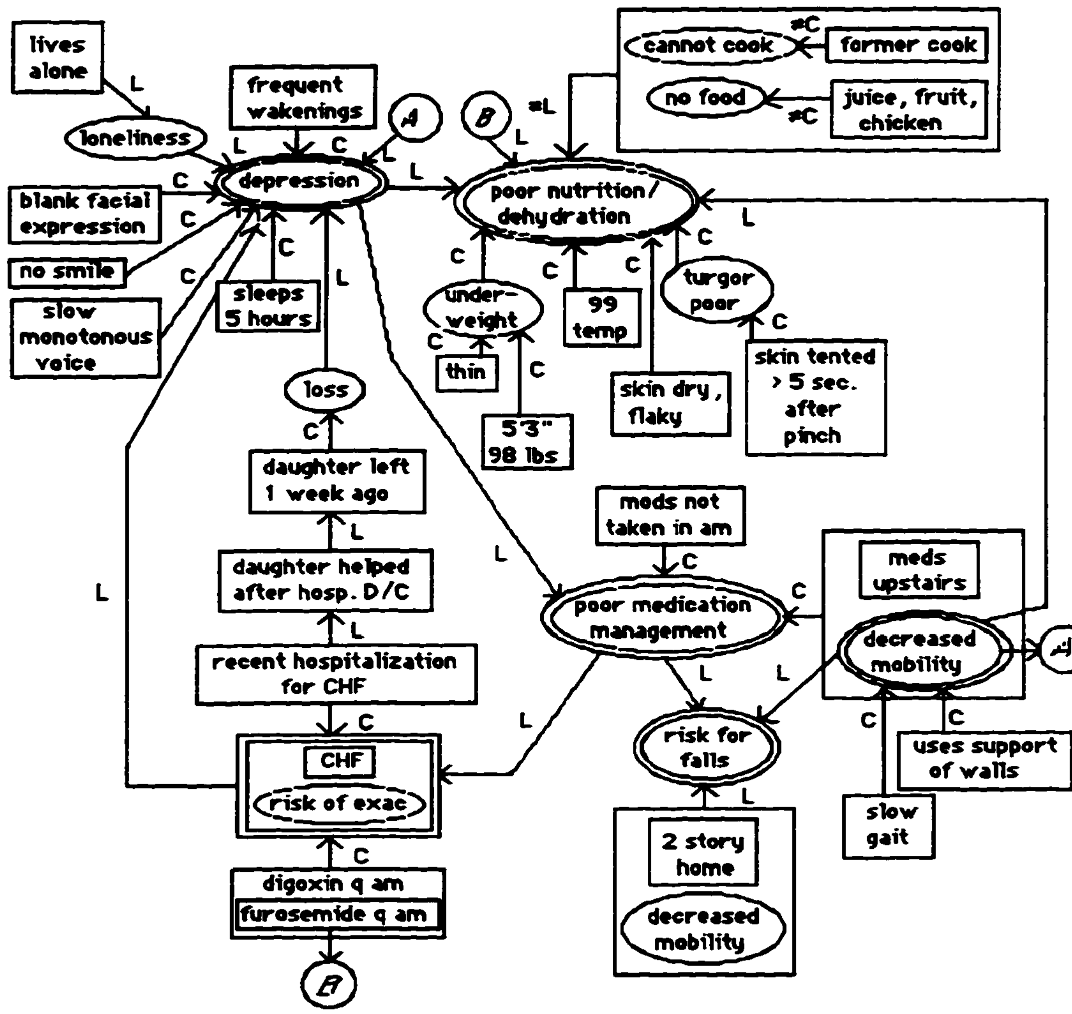
Rule 4: Problems that were identified in response to the question "Are there any other problems you feel might occur if no interventions are instituted?" were graphed in the same manner as above, and marked with "†" to indicate that this information was prompted.

Figure 1 shows the researcher's model of a conceptual graph structure of the patient scenario. Problems associated with the study's six primary concepts are identified by double lined enclosures.

2. <u>Cohesion of problem representation</u>. Cohesion of problem representation

refers to the degree of interconnection perceived among the "patient's" problems and

Figure 1. Researcher's Model of a conceptual graph structure of the patient scenario



associated data and inferences. For example, the "patient" may be viewed as having several concurrent, yet unrelated, problems coexisting within the individual (low cohesion). Or the "patient" may be viewed as having several concurrent problems which interact with and affect each other (high cohesion). High cohesion of problem representation reflects a more dynamic perception of the "patient."

Two methods to measure cohesion were used. First, an index of problem density was determined by calculating the mean number of relational links per problem node, reflecting the degree of interconnection of problem data and inferences with the identified problems. Then, an index of cohesion was determined by calculating the number of causal associations directly linking the "patient's" problems, reflecting the degree to which participants viewed the problems as interacting with and affecting each other. The Researcher's Model of a conceptual graph structure of the patient scenario has a problem density of 6.17 and a cohesion index of 9.

After this initial analysis, the researcher compared the data from novice and expert participants and identified the presence of patterns and consistencies within the novice and expert groups. Findings from novices and experts were compared for similarities and differences. Of particular interest were:

1. Pattern recognition

    - Patient problems that were identified, including level of the stated problem. For example, identification of a sign or symptom as a problem to be addressed, such as poor skin turgor, reflecting only superficial conceptualization of the problem. Or a identification of dehydration as the problem, reflecting deeper conceptualization.
    - Errors in pattern recognition, including incorrect problem (ex., safety identified as a problem related to orange juice and package of chicken kept next to each other in the refrigerator), incomplete problem (ex., only dehydration identified as a problem rather than both poor nutrition and hydration), failure to recognize a problem, or erroneous characteristics given in support of a problem (ex., characteristics that were not stated or implied in the case study).
    - Identification of potential problems. In addition to the potential

for falls or for exacerbation of CHF, participants may have identified other problems that might occur without appropriate interventions, such as potential for altered mental status related to dehydration.

2. <u>Inference</u>

- Number and type of inferences, including definitely stated versus tentatively stated.
- Inferred relationships among concepts that were stated to support identification of problems (both facts given in the case study and inferences derived from the given information).
- Errors in characteristic inference.
- Errors in causal inference, such as implausible or incorrect causal statements.

<u>Think-Aloud: Predictions Regarding Problem Representation</u>

Based on what is known from previous research about differences in novice and expert problem solving, several predictions were made about the findings from Exercise 2. First, it was predicted that novices would demonstrate inferior pattern recognition abilities compared to experts, demonstrated by a greater number of incorrect or incomplete problems identified, as well as failure to identify some problems. It was predicted that experts would be more likely to correctly identify problems than novices, especially problems that have the potential to occur. Second, experts' problem representations would demonstrate a greater cohesion than those of novices. Third, experts would make a greater number of correct inferences, of both characteristic and causal types, than would novices. Also, novices would tend to make more errors in the inferences they generate.

Knowledge Structures and Problem Representation

Previous research has shown that a more extensive and interrelated knowledge structure in a domain enables superior problem solving performance, including pattern recognition and inference. However, it is unclear what specific characteristics of underlying knowledge structures contribute to this ability, particularly when the task is to identify and solve multiple interacting problem entities, both actual and potential, some of which may require conflicting solutions.

In this portion of the study, information on participants' underlying knowledge structures (obtained from the question answering task) and problem representation (obtained in the think-aloud task) were used to examine the third research question: How does the organization of the underlying knowledge base relate to problem solving performance on problems involving multiple interacting problem entities?

In order to explore this question, the data was examined from several perspectives: (1) prediction of problem representation from general knowledge structures; (2) knowledge regarding conditions of applicability of structural knowledge within a problem context; and (3) relationship between interconnectivity of structural knowledge and cohesion of problem representation.

Knowledge Structures and Problem Representation: Data Analysis

1. Prediction of problem representation from general knowledge structures. It appears reasonable to assume that when individuals' underlying organization of knowledge structures are highly congruent with the data in a problem situation, they will be more apt to develop an accurate representation of the problem. Similarly, it appears reasonable to assume that when individuals' underlying knowledge structures related to concepts in a problem contain incomplete associations, they will be less apt to develop accurate representations of the problem. Chi, Glaser, and Rees (1982) concluded as much in their study of differences between novices and experts in physics

and attributed the generation of inference errors during problem solving by novices, at least in part, to incomplete knowledge links between relevant nodes in underlying knowledge.

Therefore, a simple prediction model based on the similarity of associations generated in the structural knowledge question answering task to associations noted in the Researcher's Model of the case study was used to predict participants' inclusion of the primary concepts and associations in their problem representations during the problem solving exercise. In this model, similar to the one developed by Gordon and Gill (1989) in their study of knowledge structures and problem solving, the concepts that a participant has identified as being associated with the primary concepts during the question answering task (either as a characteristic or causal relationship) was compared with the Researcher's Model of the case study. If one or more of a participant's associations were identical or highly similar to the Researcher's Model, the prediction was made that the participant would identify a problem associated with that primary concept during the think-aloud problem representation task. Also, if a participant did not identify associations similar to those in the Researcher's Model, the prediction was made that the participant would not identify a problem associated with that primary concept during the think-aloud problem representation task. Causal associations for the concepts related to potential problems (CHF and falls) were also specifically examined for their value in predicting whether or not participants identified potential problems in these areas.

This very simple model is based on the following assumptions adapted from Gordon and Gill (1989):

1. Individuals have stored information relevant to the domain in associative knowledge structures.

2. During problem solving in the domain, the concepts in the problem

statement that map onto or match concepts in the individual's knowledge structures are activated.

3. Activation spreads from the nodes activated by the problem statement to related nodes in the knowledge structures.

4. Associations that provide directly usable knowledge will be acted on as a step in the problem solving process.

Additionally, it is assumed that associations indicating a characteristic or causal relationship are particularly relevant in the development of problem representations in the domain of home care nursing.

Therefore, in the prediction model it is assumed that when data in the problem statement (Case Study) map onto concepts that participants have associated with the study's primary concepts in a characteristic or causal relationship (demonstrated in the question answering task), the primary concepts will become activated and used by participants in the development of the problem representation during the think-aloud task. Conversely, it is assumed that when data in the problem statement is not associated with the study's primary concepts in the question answering task, the primary concepts will not become activated during problem solving because participants do not have such associations in their underlying knowledge structures, or because these associations are so weak that they were not readily identified during the question answering task.

For example, the Case Study included the statement that the "patient's" skin "remains tented more than 5 seconds after it is pinched." The Researcher's Model indicates that poor skin turgor can be inferred from this statement because skin tenting is a characteristic of poor skin turgor. Likewise, because dehydration is characterized by poor skin turgor, dehydration can be inferred from the statement that the skin remained tented. If during the structural knowledge question answering task participants noted an association between skin tenting or poor skin turgor and dehydration, it would be predicted that the concept of poor hydration would be included in the problem representations of those participants. Conversely, if during the question answering task, participants did not associate skin tenting or poor skin turgor with poor hydration, it would be predicted that poor hydration would not be included in their problem representations.

Predictions were compared to participants' actual problem representations to test for accuracy of the model. Possible outcomes include the following:

1. + + (predicted inclusion of primary concept, actual inclusion of primary concept)
2. - - (predicted exclusion of primary concept, actual exclusion of primary concept)
3. + - (predicted inclusion of primary concept, actual exclusion of primary concept)
4. - + (predicted exclusion of primary concept, actual inclusion of primary concept)

The first two outcomes represent accuracy of the prediction model. The last two outcomes represent errors in the prediction model.

2. Conditions of applicability of underlying knowledge. One characteristic of expert problem solvers is that they have more knowledge about the conditions of applicability of underlying knowledge to a problem solving situation (Chi, Glaser, & Rees, 1982). Experts are generally superior to novices in correctly recognizing when to apply their underlying knowledge to problem solving situations.

Ability to recognize the conditions under which structural knowledge applies to a problem solving situation was examined by comparing whether or not novices and experts identified problems in the case scenario when the applicable knowledge was demonstrated to exist. This was done using data from the prediction model, comparing novices' and experts' "+ +" and "+ -" results. In both of these situations, concepts were listed by participants in the structural knowledge exercise that were associated in an identical or highly similar manner to concepts in the case scenario. Of interest are differences between novices and experts regarding whether or not they applied this knowledge during problem representation for both actual and potential problems.

3. Relationship between interconnectivity of structural knowledge and cohesion of problem representation. Recall that organization of underlying knowledge is related to ability to solve problems, such that a highly organized and interconnected knowledge structure is essential for expert problem solving performance (Chi, Glaser, & Rees, 1982; Robertson, 1990). An organized and interconnected knowledge structure contributes to the expert's ability to recognize patterns in the problem data and to make inferences, which results in superior problem representation (Chi, Glaser, & Rees, 1982). Therefore, it was expected that participants whose structural knowledge is more highly interconnected would develop a more cohesive problem representation.

Knowledge Structures and Problem Representation: Predictions

Based on previous research regarding knowledge structures and problem representation, several predictions can be made. First, the prediction model would be more accurate than erroneous (more hits than misses) in predicting the inclusion or exclusion of the primary concepts in participants' problem representation for both novices and experts. In addition, accurate predictions for the expert would most likely be based on the similarity of the participant's associations related to the primary concepts that were stated in the question answering task (structural knowledge) to the associations related to the primary concepts in the Researcher's Model ("+ +" hit). In contrast, accurate predictions for the novice would more likely be based on the participant's inability to identify associations related to the primary concepts in the question answering task (structural knowledge) that were similar to the associations with those concepts in the Researcher's Model ("- -" hit).

This would be congruent with the assumption that when data in the problem statement (Case Study) map onto concepts that participants have associated with the study's primary concepts in a characteristic or causal relationship (demonstrated in the question answering task), the primary concepts will become activated and included by participants in the problem representation. Conversely, when data in the problem statement is not associated with the primary concepts (demonstrated in the question answering task), the primary concepts will not be activated during problem solving because such associations are either absent or so weak that they were not identified during the question answering task. Such incomplete associations among problem concepts were found to contribute to novices' errors in physics problem solving by Chi, Glaser, and Rees (1982).

Second, it was predicted that when relevant underlying knowledge is demonstrated to exist, experts would be more likely than novices to correctly apply this knowledge in a problem situation. Specifically, it was expected that experts would identify more problems associated with the primary concepts during problem representation than would novices, even when both groups had the related knowledge of concepts in their underlying knowledge base.

Third, it was expected that there would be a positive relationship between degree of interconnectivity among concepts in structural knowledge and cohesion of problem representation. This is because an organized and interconnected knowledge structure contributes to the expert's ability to recognize patterns in the problem data and to make inferences, resulting in superior problem representation.

CHAPTER 4

RESULTS

Research Questions

1. What are the similarities and differences in underlying knowledge structures between novices and experts in home health care nursing?

2. What are the similarities and differences between novices and experts in home health care nursing in ability to recognize patterns in problem data and to make inferences for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health nursing?

3. How does the organization of the underlying knowledge base relate to problem representation for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

Knowledge Structures

Knowledge structures were measured by the question answering task to identify concepts that participants link to the study's primary concepts in a "characteristic of" or causal relationship. Information obtained was used to answer the first research question: What are the similarities and differences in underlying knowledge structures between novices and experts in home health care nursing?

Quantitative Findings. Table 1 presents the total number and percentage of characteristic and causal statements for each participant. Interrater agreement was 98%. Differences between raters were determined by the researcher. The five expert participants are identified as E1 through E5. The five novice participants are identified as N1 through N5.

As a group, experts and novices listed the same proportion of characteristic statements (56%) to causal statements (44%). However, the experts listed a much greater number of both characteristic statements ($M = 62.8$, $SD = 18.52$) and causal statements (M = 49.6, SD = 17.35) than did the novices (M = 36.2, SD = 9.24 and M = 29.0, SD = 5.06, respectively). This supports the expected outcome, that in general experts would be able to recall a greater number of concepts related to the study's primary concepts. However, this was not uniformly true of all participants.

Table 1

Total Characteristic and Causal Statements by Experts and Novices

	Characteristic		Causal		Total	
Participant	#	%	#	%	#	%
E1	47	60%	31	40%	78	100%
E2	64	44%	80	56%	144	100%
E3	55	50%	54	50%	109	100%
E4	98	67%	48	33%	146	100%
E5	50	59%	35	41%	85	100%
Total	314	56%	248	44%	562	100%
N1	47	64%	27	36%	74	100%
N2	27	57%	20	43%	47	100%
N3	34	52%	32	48%	66	100%
N4	26	45%	32	55%	58	100%
N5	47	58%	34	42%	81	100%
Total	181	56%	145	44%	326	100%

Individually, two of the experts, E1 and E5, were very similar to two of the novices, N1 and N5, in the number and proportion of statements they offered for both categories. However, experts E2, E3, and E4 stood out as offering a significantly greater number of characteristic statements (64, 55, and 98, respectively) and causal statements (80, 54, and 48) related to the study concepts than did any of the novices or the other two experts.

The backgrounds of the experts were examined for factors that might account for the differences among them. Expert E1 had the least amount of experience as an RN

(6 years) and as a home care nurse (5 years) compared to the other participants. Expert E5 had the greatest amount of experience as an RN (24 years) yet had only 6 years of experience as a home care nurse. Although it might be surmised that these experts' lower number of years of home care experience might account for the differences in their number of responses compared to the other experts, it must be noted that one other expert, E3, had 7 years of home care experience (E2 and E4 both had 13 years of home care experience), yet E3 listed a total of 109 statements. The only factor participants E1 and E5 had in common that distinguished them from the other experts was completion of a master's degree in nursing, E1 as a clinical nurse specialist/ education and E5 as a family nurse clinician. It is not clear what influence, if any, possession of a master's degree in nursing would have in explaining the differences among the experts. In the present study, no additional information that might account for the differences among the experts was available.

Participants' statements were also evaluated to determine if they were correct or not. The percent of individuals' responses that were judged to be correct characteristic and causal statements by the raters are presented in Table 2. Interrater agreement was 91%. Differences between raters were determined by the researcher.

Only a slightly greater proportion of characteristic and causal statements were correct for experts (96%) than for novices (95%). Novices N1, N2, and N3 were the only individuals whose characteristic or causal statements were less than 90% correct. The other novices had a high percentage of statements in both categories that were correct.

Finally, participants' statements related to each primary concept were examined for interconnectivity with the other primary concepts and statements. The total number of statements, number of interconnected statements, and percentage of interconnected statements are listed in Table 3.

Table 2

Percent of Correct Characteristic and Causal Statements

Participant	Characteristic	Causal	Total
E1	96%	97%	96%
E2	95%	95%	95%
E3	96%	100%	98%
E4	92%	94%	92%
E5	100%	97%	99%
Mean	95%	96%	96%
N1	89%	96%	92%
N2	96%	85%	91%
N3	88%	100%	94%
N4	96%	100%	98%
N5	96%	100%	98%
Mean	93%	97%	95%

Table 3

Interconnections Among Characteristic and Causal Statements Listed for Primary Concepts

Participant	Total Number Statements	Number Interconnected	Percentage Interconnected
E1	78	31	40%
E2	144	28	19%
E3	109	32	29%
E4	146	49	34%
E5	85	30	35%
Total	562	170	30%
N1	74	12	16%
N2	47	11	23%
N3	66	20	30%
N4	58	12	21%
N5	81	20	25%
Total	326	75	23%

In general, expert participants did have a greater number and percentage of interconnected statements than did the novices, as was expected. The only exceptions were participants E2, who had a much lower proportion of interconnecting statements than the other experts (19%), and N3, who had a somewhat higher proportion of interconnecting statements than the other novices (30%). Interestingly, although E1 and E5 were very similar to N1 and N5 in number of characteristic and causal statements, their percent of interconnections was significantly higher.

Qualitative Findings. There were qualitative similarities in the types of statements associated with the study's primary concepts made by experts and novices. Members of both groups noted factors that could be verified only through laboratory testing, such as "anemia," "decreased serum albumin," and "digoxin level high." Also, both novices and experts were able to state many and varied outward signs or objective observations that might be characteristic of patients with problems related to the primary concepts, for example, "edema," "unsteady gait," "cough," "dry skin," and "poor skin turgor." Such laboratory tests and objective signs would be common to patients in any practice setting, including both hospital and home care. Therefore, it was not surprising to see these similarities.

There were also several qualitative differences between experts' and novices' statements. Experts listed a greater number and variety of statements that related to social and environmental characteristics and causes than did the novices, for example, "lack of social support," "no support system to prepare food," "lack of support from family or friends," "low income," "no safety rails on stairs," "multiple environmental hazards," and "improper/poor lighting." Experts also noted a greater number and variety of symptoms or subjective information about patients that would be known or verified only through history taking, questioning, or interviewing patients or their caregivers, such as "confusion from too many meds," "complains of pain on walking," "denial," "decreased appetite," and "change in taste/poor appetite."

Problem Representation Ability

Problem representation was measured using a think-aloud question answering task after participants had read a patient scenario involving the same six concepts as used in the structural knowledge task. Information obtained was used to answer the second research question: What are the similarities and differences between novices and experts in home health care nursing in ability to recognize patterns in problem date and to make inferences for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

Conceptual Graph Structures

Information obtained during the think-aloud task was translated into conceptual graph structures to model participants' problem representation, including pattern recognition and inference generation. Participants' conceptual graph structures are displayed in Figures 2 through 11. The following are the codes used in the conceptual graphs:

L = leads to (causal link)

C = characteristic of

≠ L = evidence that content of node does not lead to content of other node

≠ C = evidence that content of node is not characteristic of content of other node

= content was stated or paraphrased from problem data

= content was inferred from problem data

= content was listed as a patient problem and was identical to or paraphrased from the scenario

= content was listed as a patient problem and was inferred from data in the scenario

? = node/relationship hypothesized by the participant or participant was not sure

* = error

† = problem was prompted during data collection

Figure 2. Participant E1's conceptual graph structure of the patient scenario

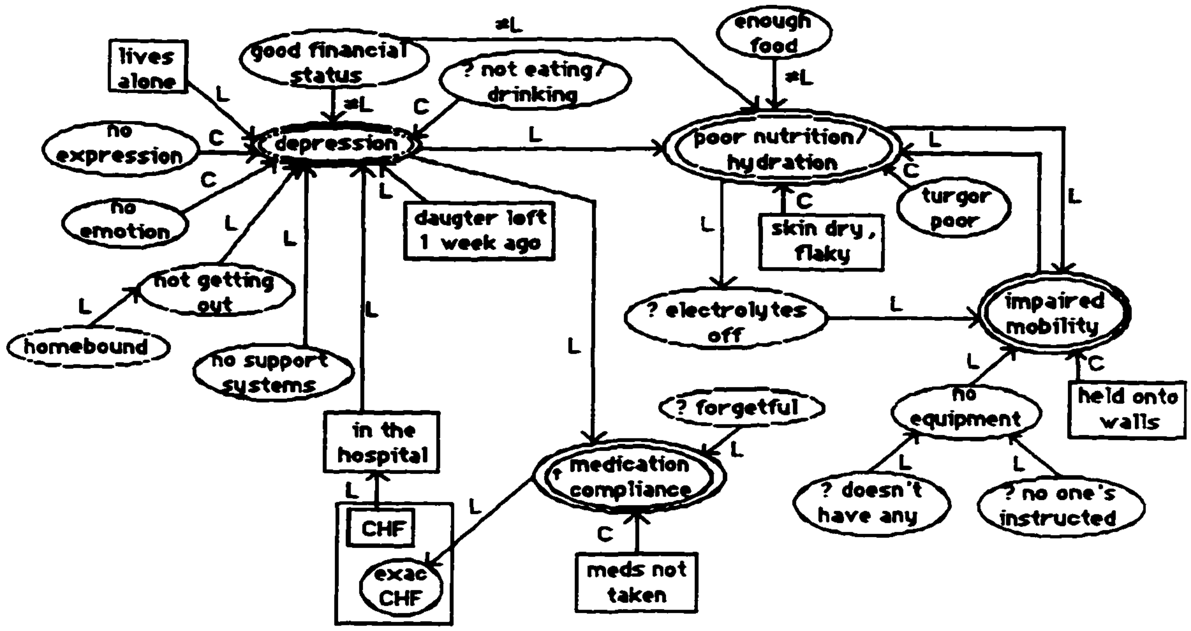


Figure 3. Participant E2's conceptual graph structure of the patient scenario

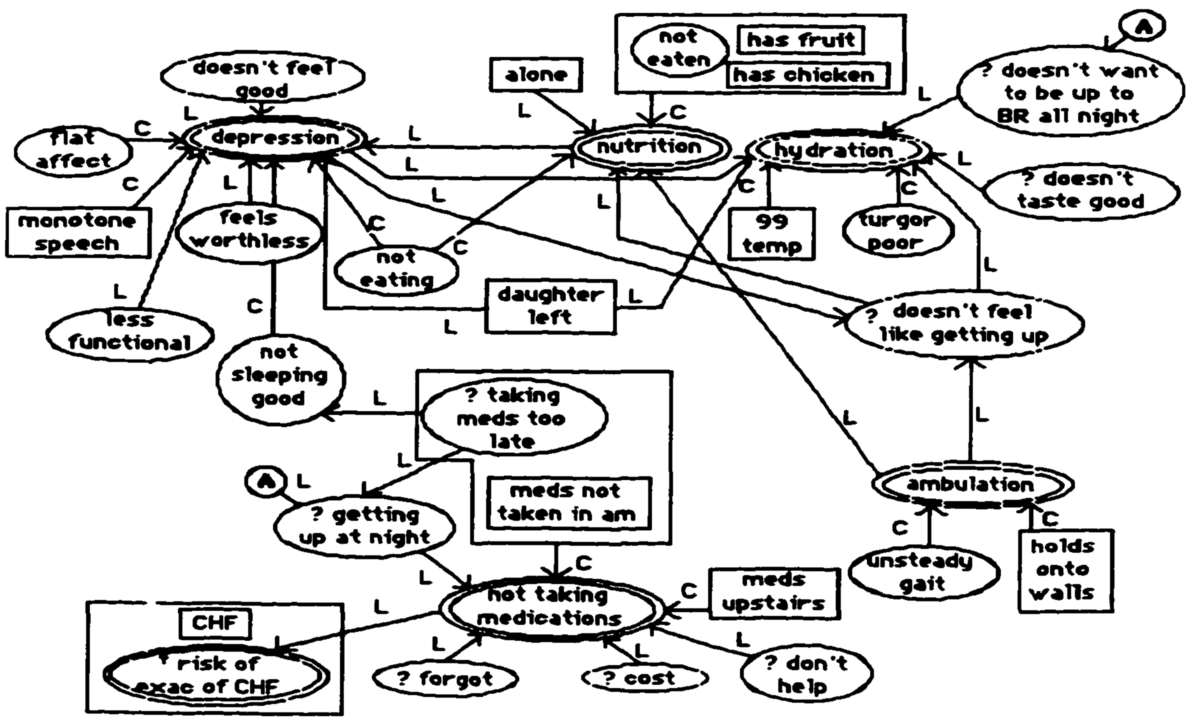


Figure 4. Participant E3's conceptual graph structure of the patient scenario

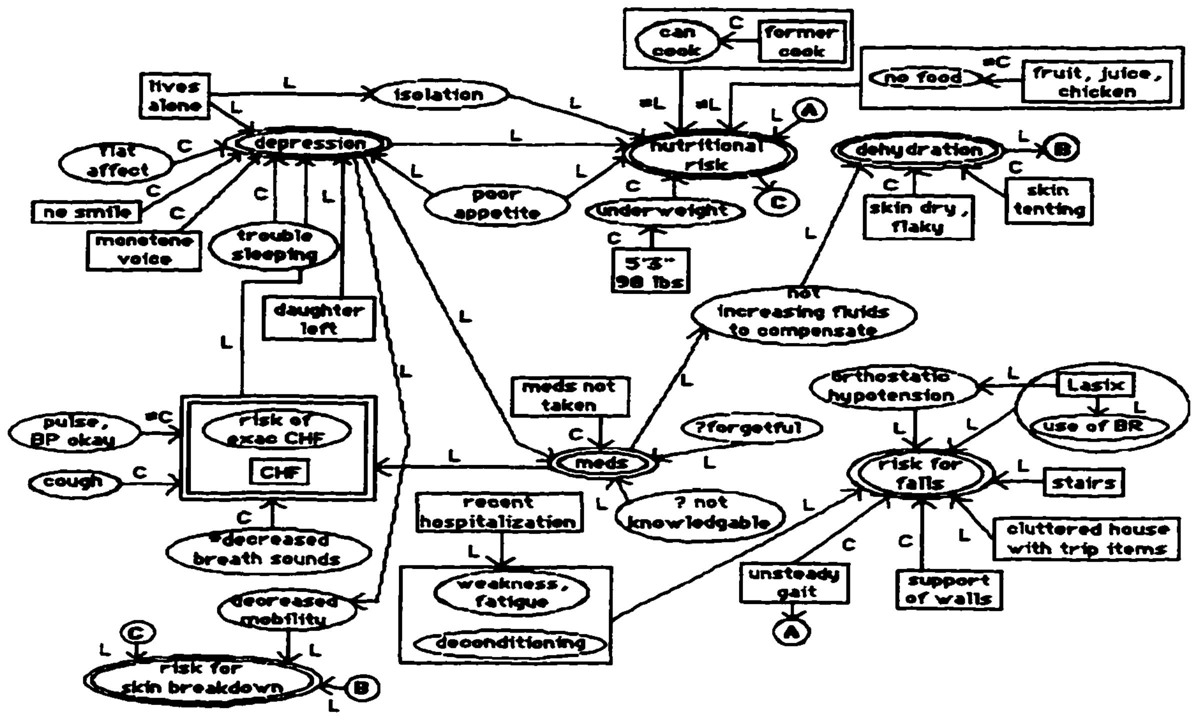


Figure 5. Participant E4's conceptual graph structure of the patient scenario

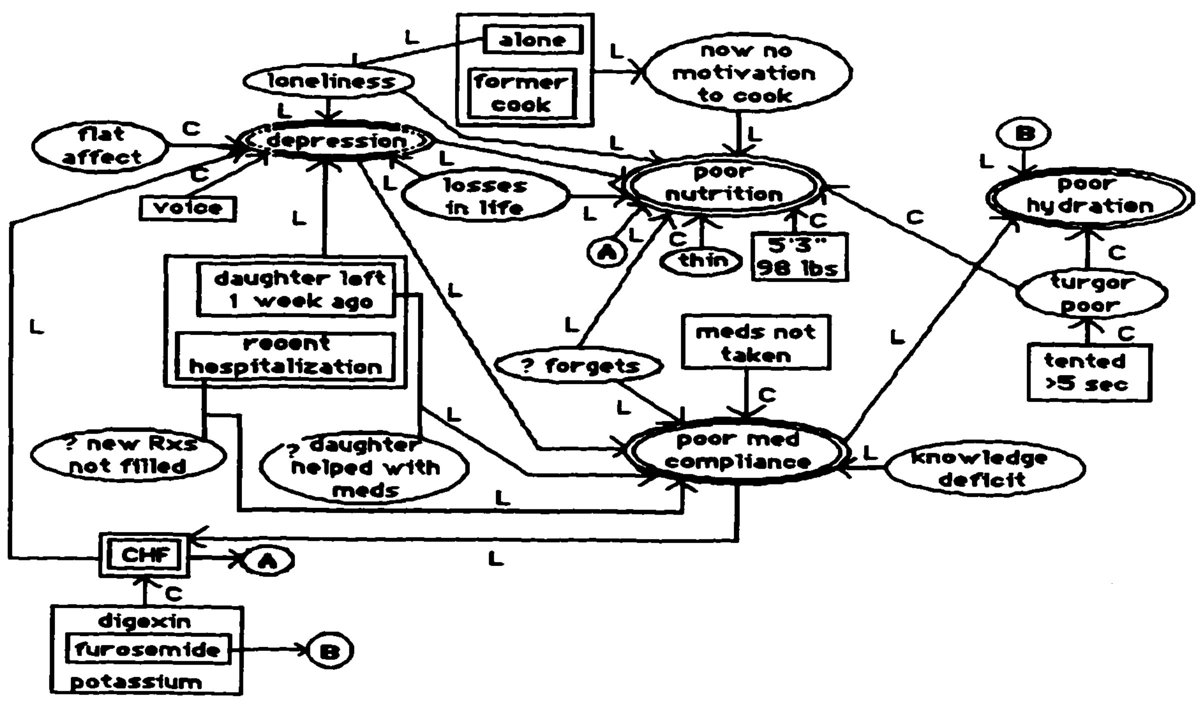


Figure 6. Participant E5's conceptual graph structure of the patient scenario

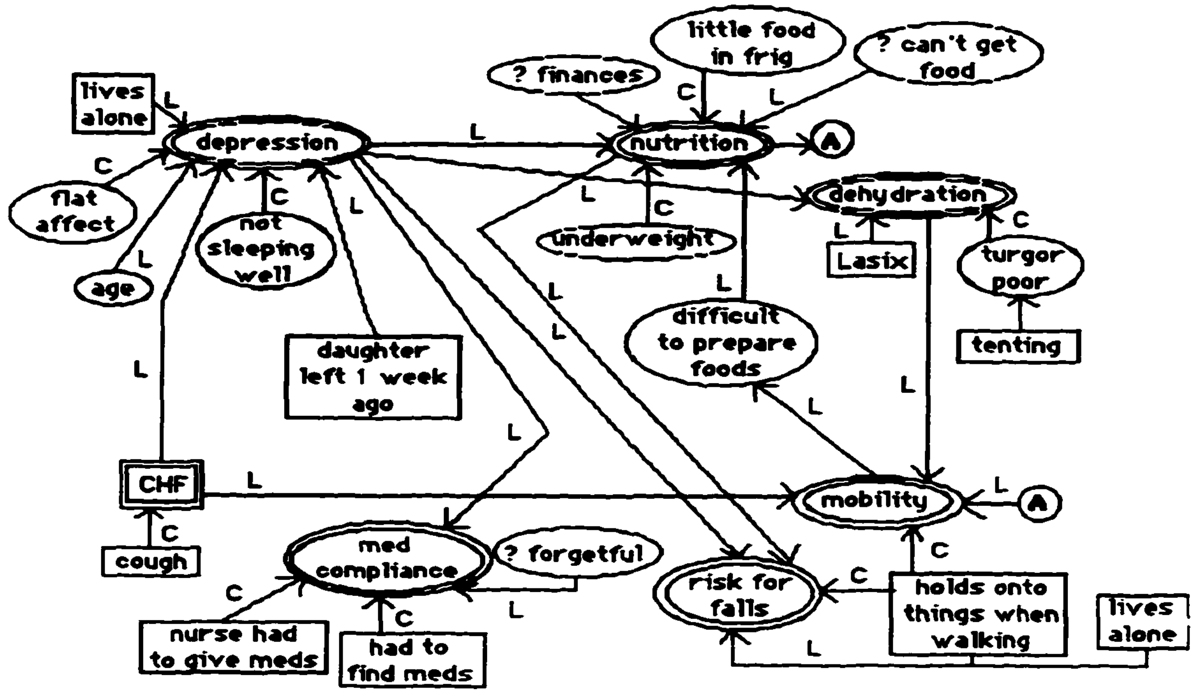


Figure 7. Participant N1's conceptual graph structure of the patient scenario

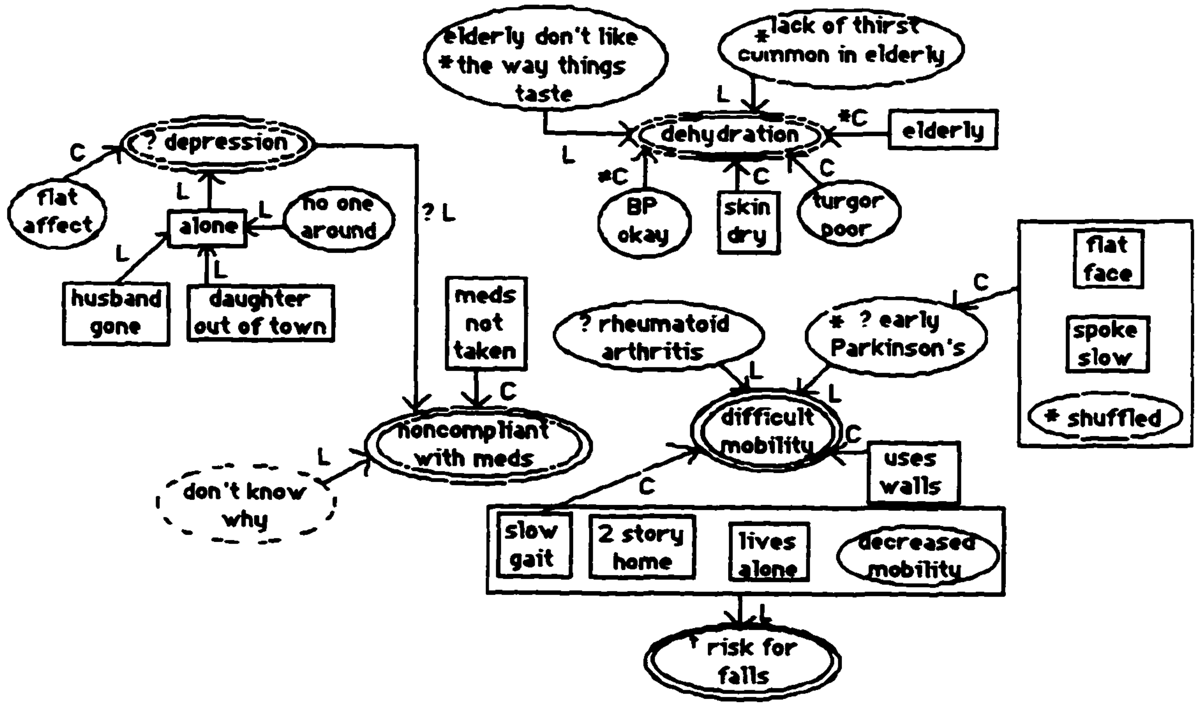


Figure 8. Participant N2's conceptual graph structure of the patient scenario

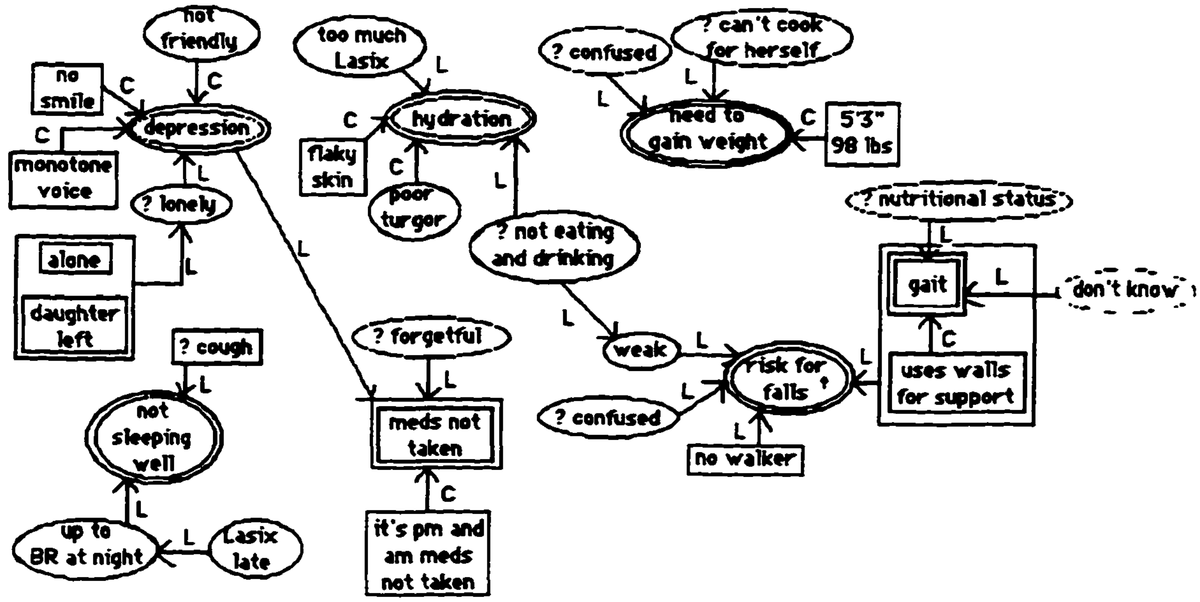


Figure 9. Participant N3's conceptual graph structure of the patient scenario

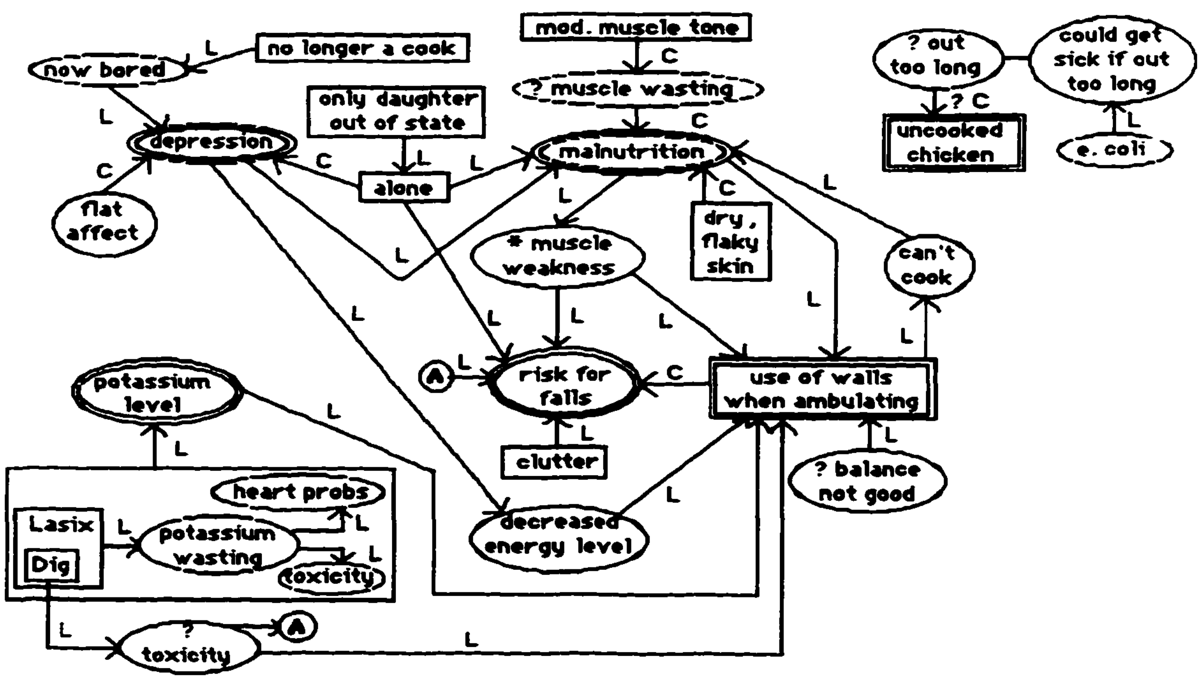


Figure 10. Participant N4's conceptual graph structure of the patient scenario

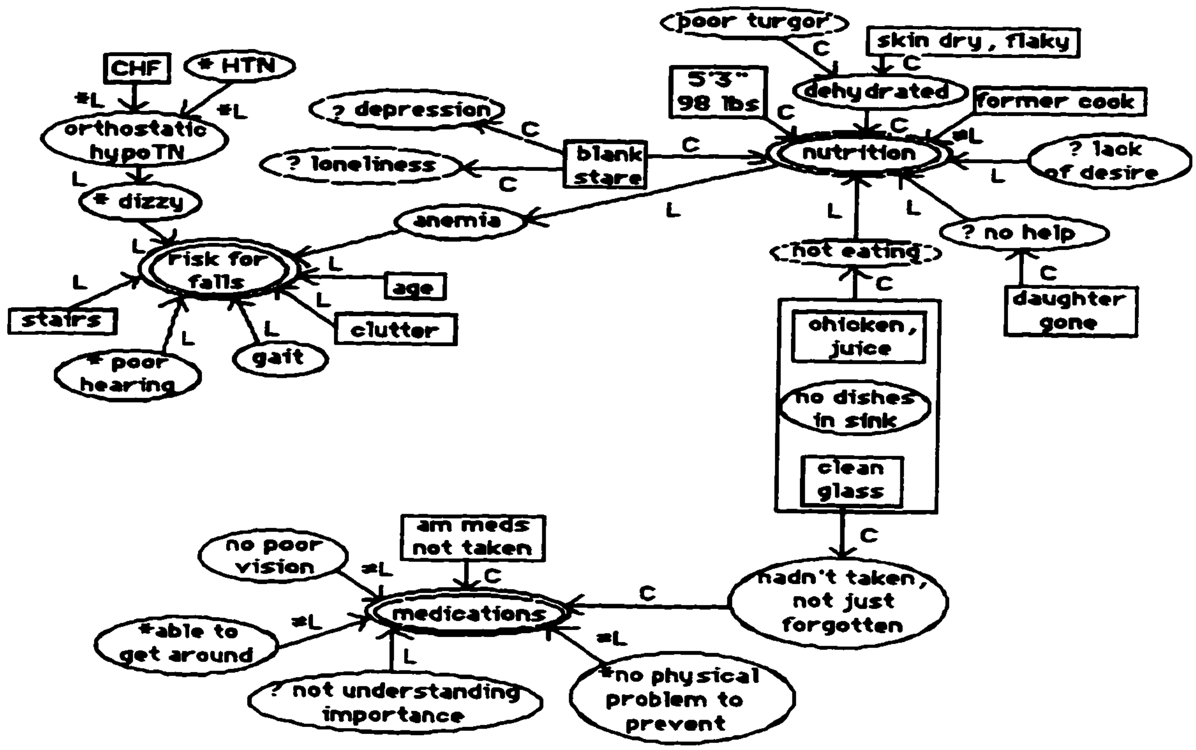
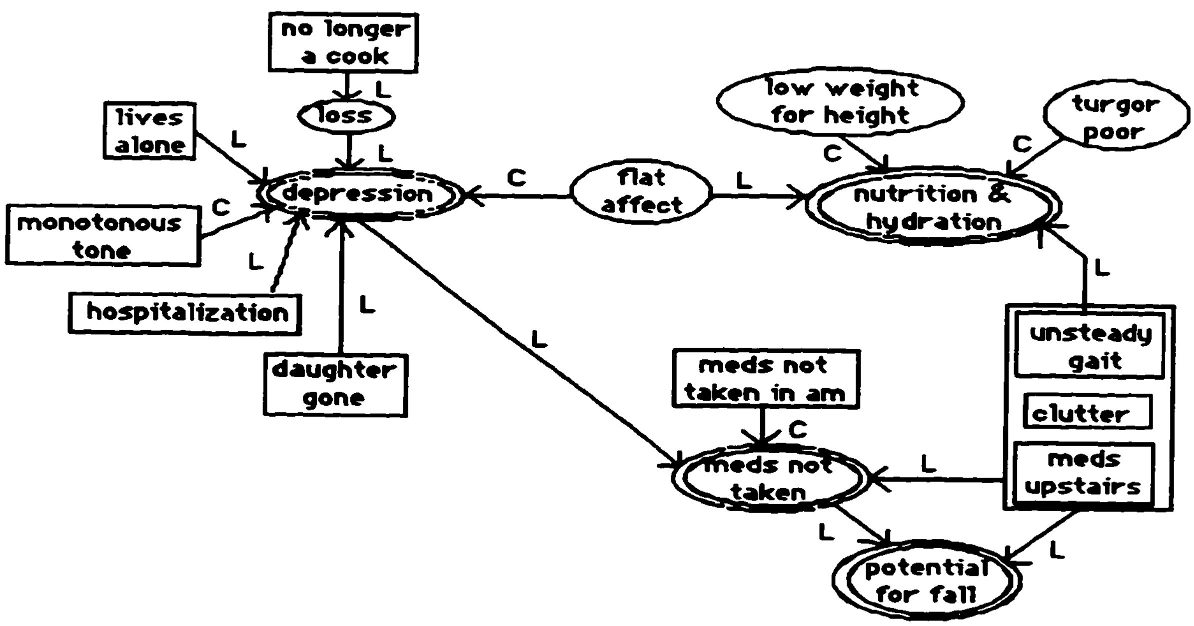


Figure 11. Participant N5's conceptual graph structure of the patient scenario



The conceptual graphs reveal that experts represented the "patient's" problems and situation as more complex and interrelated than did the novices. Experts were able to offer extensive explanations of the problems they felt should be addressed by the home care nurse, including both characteristic and causal relationships. Novices' conceptual graphs were less extensive and interrelated, and generally contained less satisfactory explanations. For example, both N1 and N2 were unable to state possible causes of one of the problems they thought should be addressed by the nurse.

Cohesion of Problem Representation

Cohesion of problem representation refers to the degree of interconnection perceived among identified problems and associated data and inferences.

Quantitative Findings. Cohesion was measured through both an index of problem density and an index of cohesion. Problem density, the mean number of relational links per problem node, reflects the degree of interconnection of problem data and inferences with identified problems. Cohesion, the number of causal associations directly linking the "patient's" problems, reflects the degree to which participants viewed individual problems as directly interacting with each other. Measures of problem density and cohesion for the conceptual graphs of participants and the Researcher's Model are presented in Table 4.

As predicted, experts' problem representations indicated a more cohesive, dynamic view of the "patient" and her problems. The one exception appears to be participant N4 who had a high density index (7.00), indicating that a relatively large number of problem data and inferences were associated with each identified problem. Upon closer examination of N4's conceptual graph, however, it can be seen that four of the inferences associated with the identified problems were erroneous. While N4's perception of the problem appears to be densely associated with inferences from the problem data, several of these inferences were incorrect. In addition, N4 had no direct links between any of the problems she identified, reflecting a perception of the "patient" situation that is rather undynamic.

Table 4

Indices of Problem Density and Cohesion of Problem Representations

Participant	Density	Cohesion
Researcher's Model	6.17	9
E1	7.00	4
E2	6.00	4
E3	6.29	6
E4	6.40	6
E5	5.83	8
Mean	6.30	5.6
N1	3.00	1
N2	3.29	1
N3	4.67	3
N4	7.00	0
N5	4.25	2
Mean	4.44	1.4

Qualitative Findings. As stated earlier, participants' conceptual graph structures demonstrate that experts' problem representations were more complex and interrelated than those of the novices. Visual inspection of the graphs reveals that all of the experts' representations consist of data and inferences that are so interrelated as to present a singular web of subproblems. Three of the novices' representations, however, consist of two or more concurrent yet unrelated groups of problems and their associations that appear as separate islands within the total representation.

Participant N1's representation consists of three such islands, each consisting of one or more stated problems and associated problem data and inferences: dehydration, difficult mobility, and depression-noncompliance with medications. N2's representation consists of four island groups: depression-medications not taken, not sleeping well, need to gain weight, and gait-risk for falls. N3's representation is generally better integrated, so that five problems are associated together with only one problem not associated with the other: uncooked chicken.

In participant N4's representation, all of the problems are integrated in some way with the others. However, the link between two of the identified problems, nutrition and medications, consists of a rather weak characteristic association rather than a stronger causal type of connection. The element that was common to both problems of nutrition and medication was "clean glass," with N4 inferring that this piece of problem data was indicative of the "patient" not taking her medications and not eating.

In contrast to those of the novices, representations of the experts are highly interrelated. For example, three of the problems identified by participant E3 were each noted as being directly or indirectly associated with at least three other problems. E3 indicated that one problem alone, depression, was related to problems in four other areas: nutrition, medications, risk for skin breakdown, and risk of exacerbation of CHF. Participant E5 identified five problem areas as being directly associated with the single problem of depression: nutrition, dehydration, risk for falls, medication compliance, and CHF. Experts' ability to associate multiple problems and potential problems with each other result in a conceptualization of the "patient" situation that is highly cohesive and dynamic.

Pattern Recognition

It was predicted that experts would demonstrate superior pattern recognition abilities compared to novices, with a greater number of correct and complete problems identified, including problems that have the potential to occur. Participants' conceptual graphs were compared to the Researcher's Model and to each other's, and this prediction was supported.

Problems identified by the experts more closely approximated those of the Researcher's Model than did problems identified by the novices. One expert, E5, identified all six problem areas that were noted in the Researcher's Model. One difference between experts' representations and the Researcher's Model was regarding whether problems with nutrition and hydration were conceptualized as a single entity or two. Four of the five experts conceptualized the problems of nutrition and hydration as separate, unique problems to be addressed, although all five included nutrition and hydration in their representations. Only one novice conceptualized nutrition and hydration as a single problem entity, while the other four novices noted either one or the other as a problem, but not both.

In general, problems noted by the experts were stated as broad concepts, demonstrating ability to view given signs and symptoms as subcomponents of higher level problems. For example, "poor nutrition," "dehydration," and "depression" were offered by experts as areas to be addressed, with scenario data cited or used as the basis of characteristic or causal inferences to support the problems (ex., "underweight," "skin tenting," "flat affect").

All participants except for one (N4) identified "depression" as a problem to be addressed. Otherwise, novices noted fewer problems matching the Researcher's Model, and some problems were stated on a lower, less encompassing level than those in the Model. For example, N2 listed as a problem "need to gain weight" rather than the more encompassing problem of poor nutrition. "Need to gain weight" is actually a patient goal rather than a problem, and reflects a more superficial conceptualization of the situation. Goals for adequate nutritional intake in this scenario would include much more than weight gain. N2 also listed "not sleeping well" as a problem, which would more accurately be considered a symptom of the broader patient problems of depression or poor medication management. Neither of the lower level concepts were associated with any other problems within N2's representation.

Participant N3 listed three concepts as problems that were reflective of a lower level conceptualization of the situation: "uncooked chicken," "use of walls when ambulating," and "potassium level." The uncooked chicken would actually be considered a sign of a possible problem but was viewed by N3 as being a problem itself, isolated from the broader problem area of nutrition. Likewise, "use of walls when ambulating" is a sign of the broader problem, mobility. "Potassium level" also reflects a limited conceptualization of a problem. Potassium level is routinely monitored in patients taking Lasix, particularly when it is given in combination with digoxin as is commonly prescribed for the management of CHF. Again, however, potassium level is merely a sign of the broader problem related to the treatment of CHF with these medications.

Novices tended to view some problems in a less complete manner compared to the experts. For example, while all of the experts noted both nutrition and hydration as problem areas to be addressed, the novices tended to identify either nutrition or hydration as problems, rather than both. Only one novice, N5, identified both.

There was failure to identify mobility as a problem to be addressed by members of both groups. Only three experts and one novice noted a problem with mobility. Two novices noted problem areas that were generally related to mobility, but these were stated at a lower level ("gait" and "use of walls when ambulating").

It was predicted that experts would be superior to novices in identifying potential problems that might occur without appropriate interventions and there were striking differences between the groups related to the identification of potential problems of CHF and falls. While all of the experts noted CHF or the potential for exacerbation of CHF as a problem to be addressed by the nurse, none of the novices did. This is particularly interesting since it was a given within the scenario that the "patient" had a history of CHF and was recently hospitalized for it.

Four of the five experts noted a problem with medication management as being directly related in a causal manner to the "patient's" potential for exacerbation of CHF. Of the four novices who did identify a problem with medication management, only one (N5) conceptualized that this problem was a causal factor associated with another problem in the representation (potential for fall).

Since the "patient" was not currently exhibiting obvious signs or symptoms of CHF, novices appeared to not recognize this as an area to be addressed. Experts recognized that CHF could still potentially occur as a problem, particularly as it related to poor medication management.

Regarding the potential for falls, only two experts noted this as an area to be addressed, while all five of the novices did. Only one expert identified mobility and falls as two distinct problem areas although four experts mentioned either falls or mobility as a problem. Three novices identified falls and mobility-related problems as two distinct areas to be addressed while two identified falls only as a problem. Samples are too small for these differences to be judged significant. However, it may be that experts tend to conceptualize falls and mobility together within a single, larger problem concept while novices tend to conceptualize falls as a problem distinct from mobility.

Participant E3 also noted a potential for skin breakdown to develop, related to decreased mobility, dehydration, and nutritional risk. No other participant identified this as an area to be addressed.

Inference

During problem solving tasks, individuals infer additional relations and constraints from the task situation. Solvers try to "understand" a problem by building a mental representation from which they can infer relations that define the situation, augmenting the information in the problem with associated information from the knowledge base. Inferences are modeled in the conceptual graph structures as characteristic and causal relations between nodes.

Quantitative Findings. The number of definitely stated and tentatively stated characteristic and causal inferences made by participants during the problem representation task are presented in Table 5. The number of errors is also included.

Table 5

Total Number of Characteristic and Causal Inferences by Experts and Novices

	Characteristic				Causal			
Participant	Definite	Tentative	Total	Error	Definite	Tentative	Total	Error
E1	6	1	7	0	17	4	21	0
E2	12	0	12	0	17	6	23	0
E3	16	0	16	1	27	2	29	0
E4	9	0	9	0	17	3	20	0
E5	10	0	10	0	15	3	18	0
Total	53	1	54	1	93	18	111	0
Mean	10.6	0.2	10.8	0.2	18.6	3.6	22.2	0
N1	9	0	9	2	7	3	10	4
N2	8	0	8	0	8	8	16	0
N3	6	1	7	0	20	4	24	1
N4	10	2	12	0	15	3	18	6
N5	5	0	5	0	11	0	11	0
Total	38	3	41	2	61	18	79	11
Mean	7.6	0.6	8.2	0.4	12.2	3.6	15.8	2.2

It was predicted that experts would make a greater number of correct inferences of both characteristic and causal types than would novices. As a group, this prediction was supported by the findings. Experts made a total of 54 definitely and tentatively stated characteristic inferences ($M =$ 10.8) and 111 causal inferences ($M =$ 22.2) while novices made a total of 41 definitely and tentatively stated characteristic inferences ($M = 8.2$) and 79 causal inferences ($M = 15.8$).

Inferential errors were found primarily among the novice participants. There were 13 total inferential errors made by the novices, 85% of which were causal errors. Only one inferential error was made by an expert and it was a "characteristic of" error.

Qualitative Findings. Novices and experts drew from similar information in the case scenario to infer problems with depression, nutrition/hydration, medication management and mobility when these problem were identified. However, novices tended to make more incorrect inferences from the data provided. The novices' errors were mainly due to attribution of inferred signs or symptoms that were incorrect (for example, "muscle weakness," "shuffled," "orthostatic hypotension," "poor hearing," "dizzy"). Only one expert made an erroneous inference. Participant E3 noted "decreased breath sounds" as a characteristic of CHF, which could not correctly be inferred from data given in the problem.

Participant N1 was unique in comparison with the other participants in that he drew upon common or "layman's" knowledge regarding the elderly in his causal explanations for why the "patient" was dehydrated rather than upon medical knowledge or facts presented in the scenario. N1 offered statements that the "elderly don't like the way things taste" and "lack of thirst is common in the elderly" by way of explanation. Also, N1 made another inferential error by noting that the "patient" shuffled, leading to a further inferential error regarding a possible cause of the problem "difficult mobility." N1 combined facts from the scenario (flat facial expression, spoke slowly) with the erroneous inference that the patient had a shuffling gait and determined that a possible cause of the problem "difficult mobility" was early Parkinson's Disease.

Participant N4 also made several inferential errors which led to an erroneous explanation of a problem. She erroneously inferred that the "patient" had hypertension, which was not likely based on facts or omissions in the scenario (blood pressure reading was within normal limits, no medications prescribed for the treatment of hypertension, no diagnosis of hypertension). N4 referred to this incorrect inference in an erroneous causal chain related to the problem "risk for falls." So while the problem identified was correct, portions of the reasoning chain supporting it were incorrect.

In addition, participant N4 made inferences as causal explanations related to two different identified problems that directly contradicted each other. At one point, N4 correctly inferred that gait was causally related to a risk for falls. Yet later, N4 incorrectly noted that the "patient" was "able to get around" and that there was "no physical problem to prevent" the "patient" from taking her medications as prescribed.

Two novices, N1 and N2, stated they were unable to offer a causal explanation for one of the problems they identified and simply stated at first that they "didn't know" why. Both, however, upon further consideration were able to offer one tentative explanation for the problem.

Finally, conceptual graphs were examined for disconfirming inferences, that is, inferences indicating that one concept is not supportive of a characteristic or causal relationship with another concept. Two novices had a total of 5 disconfirming inferences while two experts had a total of 7 disconfirming inferences. There was not a clear pattern to these types of inferences, although the majority of them related to the problem of nutrition/hydration for both novices and experts.

Knowledge Structures and Problem Representation

Relationships between knowledge structures and problem representation were explored using information obtained during the question answering task and think-aloud problem solving task. Data from these exercises were used to answer the third research question: How does the organization of the underlying knowledge base relate to problem representation for problems involving multiple interacting problem entities, both actual and potential, in the domain of home health care nursing?

Prediction of Problem Representation from Knowledge Structures

A simple prediction model was used to determine if similarity of concepts in participants' structural knowledge to those of the Researcher's Model could predict identification of problems with the primary concepts in the participant's problem representation. Predictions were compared to participants' actual problem representations to test for accuracy of the model. Possible outcomes include the following:

1. + + (predicted inclusion of concept, actual inclusion of concept)
2. - - (predicted exclusion of concept, actual exclusion of concept)
3. + - (predicted inclusion of concept, actual exclusion of concept)
4. - + (predicted exclusion of concept, actual inclusion of concept)

The first two outcomes represent accuracy of the prediction model, or hits. The last two outcomes represent errors in the prediction model, or misses. The number of hits and misses are presented in Table 6.

The prediction model was much more accurate in predicting inclusion or exclusion of problems in the representation for the expert participants than it was for the novices. The model's prediction accuracy was almost 80% for experts compared to 60% for the novices.

It was anticipated that the prediction model's accuracy for the experts would most likely be based on the similarity of associations related to the primary concepts ("+ +" hits), while accuracy for the novices would most likely be based on inability to identify associations related to the primary concepts ("- -" hits). This was not supported by the findings, as there were very few "- -" hits for either group.

Larger differences were found between the two groups related to the number and type of misses. Novices had twice as many misses (12) as did the experts (6). A greater proportion of misses for the experts tended to be "+ -" misses while the number of misses for the novices were evenly split between "+ -" and "- +" types. These outcomes indicate that both novices and experts were able to recall and list concepts from the underlying knowledge base that were related to the primary concepts in the case scenario, yet novices less frequently associated these same concepts with the primary concepts when presented within a case scenario.

Table 6

Prediction of Problem Representation From Knowledge Structures

	Hits		Total Hits	Misses		Total Misses
Participant	+ +	- -		+ -	- +	
E1	4	0	4	1	0	1
E2	3	0	3	1	2	3
E3	5	0	5	1	0	1
E4	4	1	5	1	0	1
E5	6	0	6	0	0	0
Total (%)	22	1	23(79%)	4	2	6(21%)
N1	4	0	4	0	1	1
N2	2	1	3	0	3	3
N3	3	1	4	2	0	2
N4	1	0	1	3	2	5
N5	5	0	5	1	0	1
Total (%)	15	2	17(59%)	6	6	12(41%)

Novices were more likely than experts to be unable to recall and list concepts from the knowledge base that were related to the primary concepts in the case scenario, yet novices did associate these concepts with the primary concepts during problem representation. There were a total of six problems that were included in the novices' representations even though the novices were unable to recall and list related concepts associated with these problems during the question answering exercise.

Data was further analyzed to specifically examine prediction of potential problems with CHF and falls from causal associations related to these concepts in participants' structural knowledge. The concept of CHF did not lend itself well to this particular analysis due to widely differing levels of causation cited between the structural knowledge and problem representation tasks. Both novices and experts cited only physiologic or disease-related causes in the structural knowledge task. Causation in the problem representation task, however, focused on patient history and treatment factors. Prediction of the potential for falls was amenable to this type of analysis as both structural knowledge and problem representation tasks appeared to elicit a similar level of causative factors.

The model accurately predicted that potential for falls would be excluded or included (hits) based solely on causal associations for four of the experts and three of the novices. From this it appears that presence of relevant causal associations in underlying structural knowledge is useful in predicting identification of potential problems in a complex problem solving task.

Conditions of Applicability of Underlying Knowledge

One characteristic of expert problem solvers is that they have more knowledge about the conditions of applicability of underlying knowledge to a problem solving situation (Chi, Glaser, & Rees, 1982). Knowledge of conditions of applicability was examined by comparing the number and percentage of problems that were either included or excluded from participants' representations, when associated concepts were listed in the structural knowledge exercise in a similar manner to concepts in the case scenario. Results are presented in Table 7.

When participants' underlying knowledge base contained associations similar to the concepts in the case scenario, experts were able to identify more problems associated with the primary concepts during problem representation than novices did, as was predicted. However, this was not consistent among all of the participants. Two novices, N1 and N5 were very similar to the experts in number of concepts included and excluded from their problem representations. N3 and N4 contributed the most to the differences seen in this regard, excluding identification of 2 and 3 problems respectively that were related to the primary concepts. From this it appeared that several of the novices may have had limited knowledge regarding the conditions of when to apply some of their underlying knowledge.

Table 7

Number of Primary Concepts Included in Representation When Associations Existed in Knowledge Structures

Participant	Included Concept	Excluded Concept
E1	4	1
E2	3	1
E3	5	1
E4	4	1
E5	6	0
Total (%)	22 (85%)	4 (15%)
N1	4	0
N2	2	0
N3	3	2
N4	1	3
N5	5	1
Total (%)	15 (71%)	6 (28%)

The results were further analyzed to specifically examine novices' and experts' ability to apply knowledge of causal associations to recognition of a potential for falls. Three novices' underlying knowledge base contained causal associations related to falls that were similar to those in the case scenario, and all three novices identified potential for falls in their representations of the problem. This was also true for two of the three experts. Thus it appears that when the novice and expert participants could recall relevant causal associations related to potential for falls, they were likely to be able to apply it in a complex problem solving situation.

Relationship Between Interconnectivity of Structural Knowledge and Cohesion of Problem Representation

It was predicted that participants whose structural knowledge is more highly interconnected would develop a more cohesive problem representation. Comparison between participants' percentage of interconnectivity of structural knowledge and cohesion of problem representation is presented in Table 8.

Table 8

Comparison of Percent Interconnected Structural Knowledge and Representation Cohesion

	Structural Knowledge	Problem Representation	
Participant	Interconnectivity	Density	Cohesion
E1	.40	7.00	4
E2	.19	6.00	4
E3	.29	6.29	6
E4	.34	6.40	6
E5	.35	5.83	8
Mean	.30	6.30	5.6
N1	.16	3.00	1
N2	.23	3.29	1
N3	.30	4.67	3
N4	.21	7.00	0
N5	.25	4.25	2
Mean	.23	4.44	1.4

Only a modest degree of association between structural interconnectivity and density of problem representation was found (r = .52), with an explained variance of .27. A somewhat higher correlation was found between structural interconnectivity and cohesion of problem representation (r = .67). Explained variance was .45, indicating that 45% of the variance in cohesion of problem representation could be accounted for by interconnectivity of structural knowledge.

CHAPTER 5

CONCLUSIONS AND DISCUSSION

This study investigated and described similarities and differences between novices and experts in home health care nursing regarding their underlying structural knowledge of the domain and ability to represent problems consisting of several concurrent problem entitites which are interacting, actual or potential. The association between the structure of domain knowledge and subsequent problem representation was also examined.

A novice/expert exploratory design was used to examine these similarities and differences. Structural knowledge was measured using a written question answering technique. Problem representation was measured using a think aloud question answering task following reading of a problem scenario.

Interpretation

Findings related to structural knowledge, problem representation, and the relationship between these two factors were presented in the previous chapter. The next section interprets these findings, particularly as they relate to previous research.

Structural Knowledge. Consistent with previous research, experts' underlying structural knowledge of the domain was found to be more accurate, extensive, and interconnected than that of the novices. While both groups' knowledge were similar in the number of associated concepts that could be verified through laboratory testing and objective observation, differences emerged in the types of knowledge related to social and environmental characteristics and causes and subjective information that could be obtained through interview. Experts listed a greater number and variety of these types of statements than the novices did.

Both of these differences are likely related to the practice setting, conditions, and goals of home care, where there is an increased focus on social and environmental factors that impact patients and their ability to manage their own care. Hospitalized patients' conditions are generally more acute and their nutritional and other care needs are provided by others in a controlled environment, so information related to home environment, social support, or self-management is less often required than for home care patients. Therefore, through their more extensive home care experience, the experts appeared to have developed broader, more interconnected knowledge structures related to social and environmental characteristics and causes of problems, as well as those that are detected through history taking or questioning rather than through direct observation or inspection. These factors are often directly related to how well a patient will be able to manage at home, and home care nurses must be aware of their importance in order to identify and address them.

In summary, previous research on novice and expert differences in underlying domain knowledge is supported by findings from the present study. As would be expected, these differences were most apparent in areas related specifically to home care practice experience, the factor that most distinguished members of the two groups. It appears that associations among concepts relevant to a domain are developed and strengthened through domain specific practice.

Problem Representation. Similar to studies in other fields, experts' problem representations were more complete, complex, and cohesive compared to those of the novices. A striking similarity in pattern recognition was found between the participants of the present study and those of the Chi, Glaser, and Rees investigations of physics novices and experts (1982). In both studies, novices and experts identified similar information from the given problem as relevant to the problem solving task, demonstrating that novices' difficulties did not stem from failure to identify relevant cues.

In the Chi et al. study, novices were as capable as experts in identifying key terms in a problem statement. In the present study, novices were also generally able to correctly identify relevant information from the scenario. What was particularly evident, however, was novices' greater likelihood of infering different meanings to some cues or to make no inference at all, particularly regarding causal inferences. This inability to accurately identify causal relations among data was likely a major contributing factor to novices' inferior ability to identify potential problems.

The novices did note some of the same occuring problems as the experts based on detection of patterns in the data. However, other problems were either not identified by the novices, or were viewed in a less complete manner or at a superficial depth of understanding. It appears that limitations in novices' pattern recognition in both the Chi, Glaser, and Rees study and the present one were associated with a limited ability to consistently generate the appropriate inferences and relations not explicity stated in the problem.

Novices in the present study also demonstrated a tendency to view the "patient's" problems with less depth and in isolation from each other (poor cohesion), a finding similar to that of Lesgold, Rubinson, Feltovich, Glaser, Klopfer, and Wang (1988) in their investigation of novice and expert radiologists' interpretations of an x-ray film. These researchers noted that compared to the novices, the experts identified a greater number of findings, a greater number of causal relations among data, and a greater percentage of findings connected to at least one other finding. The novice radiologists' representations, as manifested in their protocols, were more superficial, fragmented, and piecemeal.

This was mirrored by findings from the present study, in which experts' conceptualizations of the problem also reflected the identification of a greater number of problems, a greater number of causal relations among the data, and a greater percentage of problems that were connected to other problems. Likewise, novices' representations were more superficial and piecemeal than those of the experts. Data from the Lesgold et al. study and from the present study support a view of the expert as doing more inferential thinking and ending up with a more coherent model of the patient in the problem situation.

Thus, as Lesgold, Rubinson, Feltovich, Glaser, Klopfer, and Wang (1988) concluded, the ability to abstract relevant underlying knowledge cued by external stimuli appears to be a differentiating factor of novices and experts. Lesgold and colleagues observed that there is a balance of pattern recognition and inference that varies with experience, and this is supported by the present study's findings.

Little research has been conducted to describe novice and expert differences in ability to recognize potential problems and the present study began to explore this area. There were too few potential problem areas included to examine recognition of potential problems in depth, however, experts did demonstrate a distinct superiority compared to novices in ability to recognize the potential for exacerbation of a medical condition as an area that should be addressed. Also, while findings related to the potential for falls were mixed, it appears there may be differences in how experts and novices conceptualize the problem of poor mobility and falls when they occur together within a complex problem solving situation. Finally, causal associations related to a concept in the underlying base appears to play a significant role in determining ability to identify potential problems.

In summary, pattern recognition and inference are two principle factors that dominate expert performance, yet they are not independent. Efficient inference making during problem solving requires recognition of relevant factors in the problem, and recognition of relevant problem data requires appropriate inference. Coordination between recognition and inference is one of the dominant process factors for expertise, and both are influenced by the structure of domain specific knowledge (Anzai, 1991).

Structural Knowledge and Problem Representation. The relationship between structural knowledge and problem representation was of major interest to the present study, and has been explored by other researchers. Chi, Glaser, and Rees (1982) suggested that when individuals' underlying knowledge structures related to concepts in a problem contain incomplete associations, those individuals will be less apt to develop accurate representations of the problem. The researchers attributed the generation of inference errors during problem solving by the novice physicists, at least in part, to incomplete knowledge links between relevant nodes in underlying knowledge.

Findings from the present study are consistent not only with the possibility of missing knowledge links, but also to the presence of weaker knowledge links as an explanatory factor for novices' lesser ability to draw appropriate inferences during problem representation. Missing knowledge associations did appear to be related to some problems not being identified during the representation task. However, if appropriate links among concepts missing from novices' knowledge structures were the sole problem, a greater number of prediction model "hits" for novices would be of the "- -" type. That is, underlying associations in structural knowledge would be absent, so no association would be made during problem representation. This was not the case, since there were very few "- -" hits for either experts or novices.

The number and types of "misses" of the prediction model were more suggestive of the possibility of weaker links among concepts by novices. The novices erred equally between noting the appropriate associations among concepts in structural knowledge but not during representation, and not noting the appropriate associations in structural knowledge but doing so during representation. It seems reasonable to assume that strong links would result in the ability to associate concepts during both free recall and problem representation, as was seen with the experts, and weaker links would result in inconsistent ability to associate concepts during free recall and problem representation, as was seen with the novices.

Chi, Glaser, and Rees (1982) also noted that expert physicists had more knowledge about the conditions of applicability of underlying knowledge to a problem solving situation. This was identified when nearly half of experts' statements related to the principle of Conservation of Energy specified the conditions under which this concept could be used, while the novices made almost none. Findings from the present study also indicate that experts possess more knowledge of applicability than novices, although through a more indirect manner than the Chi et al. studies.

In the present study, when novices did recall and list concepts from underlying knowledge in an appropriately linked relationship to the primary concepts, they still experienced difficulties correctly associating these same concepts with the primary concepts when presented within a case scenario. This difficulty did not occur with the experts. In other words, for those instances when both novices' and experts' underlying knowledge base contained associations similar to the concepts in the case scenario, the experts were more likely to apply that knowledge correctly to the representation task.

Finally, the relationship between interconnectivity of structural knowledge and cohesion of problem representation was explored. An organized and interconnected knowledge structure has been identified as contributing to the expert's ability to develop a superior problem representation (Chi, Glaser, & Rees, 1982). Since development of a coherent, integrated representation is one hallmark of a superior representation (Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988), it was reasonable to examine the relationship between interconnectivity of structural knowledge and cohesion of problem representation.

A moderate positive relationship between these two factors was found, as was expected. That is, degree of interconnectivity of structural knowledge is positively associated with cohesion of problem representation in persons with varying experience in a domain, and interconnectivity of structural knowledge can helpful in predicting cohesion of problem representation.

Limitations of the Study

This study's methods and materials were generally satisfactory in meeting the goals of the study. One limitation of note involves the use of the Researcher's Model, a conceptual graph structure developed by the author, as the comparison for participants' conceptual graph structures. Consequently, there resulted some subjectivity in the analysis of findings. Other researchers may conceptualize the study scenario in a different manner and come to alternate conclusions. Other limitations were due mainly to sample size, selection of participants, and the measurement of structural knowledge.

Because of the complexity of the data analysis, the number of participants had to be kept low and this consequently limits generalizability of the findings. However, this is a common problem found in studies of novice and expert differences in problem solving, as the majority of studies involving this type of analysis have used small numbers of participants. Researchers and readers must consequently take this limitation into account when interpreting findings.

Another source of some frustration that has also been noted in other studies of novice and expert differences is the method or criteria used to select participants. The common approach, which was the one used in the present study, is to base expertise level on the amount of experience in the domain of interest. This may not be the most differentiating factor possible, as many readers are aware of individuals with extensive experience in a domain who can at best be considered mediocre. While attempts were made to compensate for this in the present study by considering subjective evaluations of participants by those who were familiar with their knowledge and expertise, there is still the possibility that all persons included in the study were not truly representative of their expertise level.

Study results at times indicated variation among individuals within the groups, and in some instances individual novices appeared to be very similar to individual experts on certain factors. Again, it is unfortunate that the sample size could not be larger to compensate for this limitation. More reliable indicators of expertise levels are needed. Perhaps findings from this study and others can provide some ideas for methods that will reliably differentiate expertise levels.

The question answering task used to measure structural knowledge employed only the same concepts that were included in the problem representation scenario. There is some concern that completion of the structural knowledge question answering task affected subsequent problem representation, such that knowledge structures were affected in a way beneficial to accessing that knowledge for problem solving purposes. Although there was no evidence of question probe intrusiveness in a study by Gordon and Gill (1989) using a similar approach, there was no feasible way to check for this effect in the present study.

Jonassen, Beissner, and Yacci (1993) suggest inserting additional concepts among those of interest to a study in order to decrease the likelihood of question probe intrusiveness. This was tried during pilot testing of the present study's materials, however doing so considerably lengthened the time commitment required by participants. Also, participants reported that they felt tired after completing the lengthy task and there was concern that fatigue would interfere with performance on the problem representation task.

While the possibility of intrusiveness remains, it was felt that this would pose a lesser threat to success of the study than participant fatigue. Future studies may want to investigate this issue in depth.

<u>Implications for Practice</u>

This study's findings may contribute to a greater understanding of knowledge organization and its contribution to the ability to recognize patterns in problem data and to make inferences. Greater understanding can facilitate development of creative methods to elicit, assess, and represent underlying knowledge structures and problem representation processes, as well as the design of instructional strategies to optimize their development.

For example, findings from this study support the use of conceptual graph structures to model problem representation, enabling both quantitative and qualitative examination of pattern recognition and inference generation. Also, the study's patient scenario provides an example of how carefully designed materials based on research regarding the cognitive processes involved in problem representation can be used to specifically elicit the type of information of interest to the researcher or instructional designer. Finally, results have implications for the design of problem solving instruction, including the emphasis of relationships among concepts, particularly casual associations, and types of application and practice exercises that may facilitate learning.

Suggestions for Further Research

There are four major suggestions for future research that emerge from the present study: longitudinal investigation of the development of knowledge structures and problem representation; further examination of the ability to identify potential problems and the underlying knowledge structures that are associated with this ability; refinement of research methods and materials; and closer examination of the development of and coordination between the processes of pattern recognition and inference.

A highly valuable next step in the continued study of knowledge structures and problem representation would be the investigation of their development over time within the same individual. In the context of the present study, measurements could be presented to students just entering the field of study (true novices), again to these same students after completion of basic science courses, and again at the completion of their program of study (beginners). Measurements could then be presented to the same individuals after they have obtained some degree of professional practice experience (intermediates) and extensive knowledge of the field (experts). Although the logistics may present a challenge to researchers taking this approach, the benefit in terms of knowledge to be gained promises to be significant.

The present study was only a beginning step in the examination of ability to identify potential problems and the underlying knowledge structures that are related to this ability. Further research that presents a greater number of opportunities to identify potential problems is needed. Carefully designed stimulus materials and methodologies will be essential so that results will allow ready identification of specific differences in representation of potential problems between novices and experts.

As more is learned about underlying knowledge structures and the pattern recognition and inference generation that occur during problem representation, the need continues for further research to develop and refine valid, reliable methods to elicit and model these processes. This is a particularly vital need as it relates to the final, and most challenging, suggestion for further research: investigation of the coordination between pattern recognition and inference, how it develops over time, and factors that facilitate or hinder its development and application. Since coordination between pattern recognition and inference appears to be one of the dominant process factors for expertise, it promises to be a key in unlocking the mysteries of human problem solving ability.

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APPENDIX A

RESULTS OF PILOT TEST

The two measures used in the study were pilot tested with two volunteers, neither of whom met full requirements for inclusion in the study. One volunteer was a retired RN with many years of nursing experience, including several years in public health and home health care nursing, and served as an "expert." Another volunteer was a senior nursing student in a baccalaureate nursing program and served as a "novice." Purposes of the pilot test were: to ensure that the measures functioned in the manner expected and that directions were understandable to subjects; to identify and correct any problems with the materials; and to obtain an estimate of time involved so that actual study participants could be informed. Pilot test results were used in refining and finalizing data analysis procedures.

Question Answering Task: Pilot Study of Materials and Results

Pilot tests of the materials were very successful in obtaining the desired data. There were no problems noted regarding readability or ability to understand directions. During the pilot test, a third question asking what interventions were indicated for problems related to each concept was included in the data collection procedure, since novice and expert differences in determining problem solutions were also of interest to the researcher. By the end of the question answering task, which took approximately one hour to complete, the volunteers reported they were tired from "thinking so much." The purpose of the study was later changed to focus solely on problem representation and not on solution development, so the third question per primary concept was dropped. This change in the study's measurement shortened the length of the question answering task and helped alleviate the problem of participants tiring before the end of the study.

Results of the pilot test generally supported the predictions. The expert recalled more total concepts that were related in a characteristic or causal manner to the primary concepts (84) than the novice recalled (64). The expert noted more correct characteristic concepts (44) with only 1 erroneous statement, while the novice recalled 28 correct characteristic statements with 5 erroneous ones. The expert also recalled more correct causal statements (37) and fewer erroneous ones (2) than did the novice (26 correct, 5 erroneous). There was only a small difference between the expert and novice in the number of interconnections among concepts noted (expert 7%, novice 6%).

Think-Aloud: Pilot Study of Materials and Results

There were no problems noted regarding readability or ability to understand directions when the think-aloud task using the patient scenario was pilot tested. The two volunteers had no complaints regarding this exercise, and reported that the activity was enjoyable.

During the pilot test, questions probing for clarification of the "patient's" problems and for interventions related to each stated problem were included in the data collection procedure. Since the purpose of the study was later changed to focus solely on problem representation and not on solution development, question probes regarding interventions were dropped. Also, question probes relating to clarification of the "patient's" problems were dropped because they seemed to cue the novice participant to rethink her initial responses and occasionally caused confusion. A few facts presented in the patient scenario were changed to make the case study more realistic, but these did not change the problems related to the concepts of interest.

Also, neither of the participants listed potential problems as areas to be addressed by the nurse. It was not possible to tell if the volunteers did not or could not think of any potential problems, an area of particular interest to the study. Therefore, it was decided that a question prompting for this possibility would be added, noting that results would have to be interpreted accordingly.

There was concern that the use of the question answering task to measure underlying knowledge structures related to the six primary concepts would influence participants' responses on the think-aloud task. That is, it is possible that being exposed to the concepts of interest in one exercise would result in participants' looking for problems related to those concepts during the second exercise. However, this did not seem to be the case.

The "expert" noted problems with three of the primary concepts, one that was indirectly related to one of the primary concepts, and none related to the other two concepts. The "novice" noted only two problems related to the concepts, one of which was partially correct (dehydration, but did not include poor nutrition) and one of which was related to the concept but was erroneous (incorrect medications rather than a problem with medication management). The novice also noted two additional problems that were not related to any of the primary concepts. It was expected that if the question answering task had acted as a cue to the participants, they would have noted a greater number of patient problems related to the concepts than what actually occurred. This is similar to the findings by Gordon and Gill (1989) that their use of question probes to assess knowledge structures just prior to problem solving did not affect subsequent problem solving activity.

The conceptual graph structures for the pilot test participants are presented in Figure 1 and Figure 2.

Figure 1. Novice's conceptual graph structure

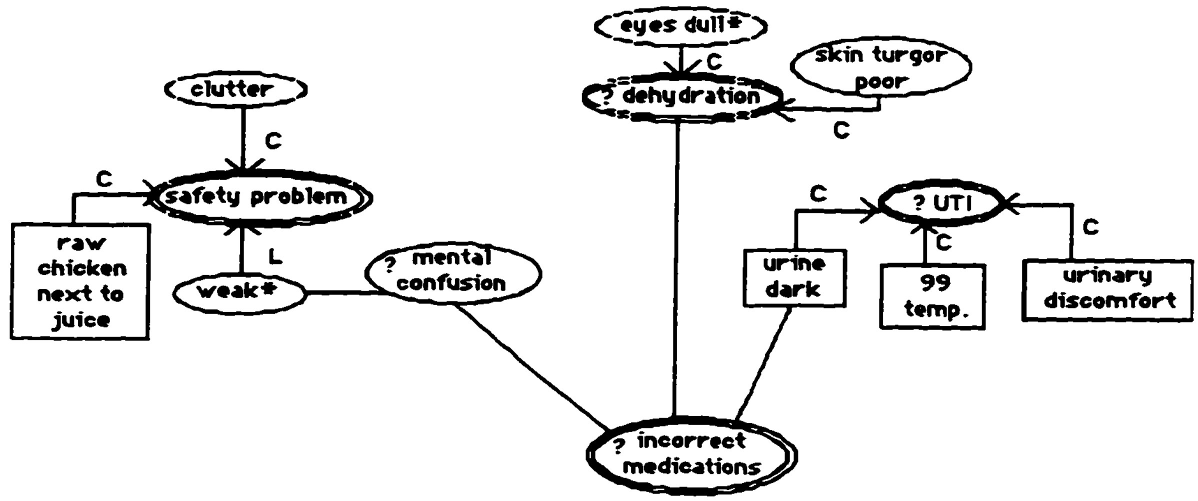
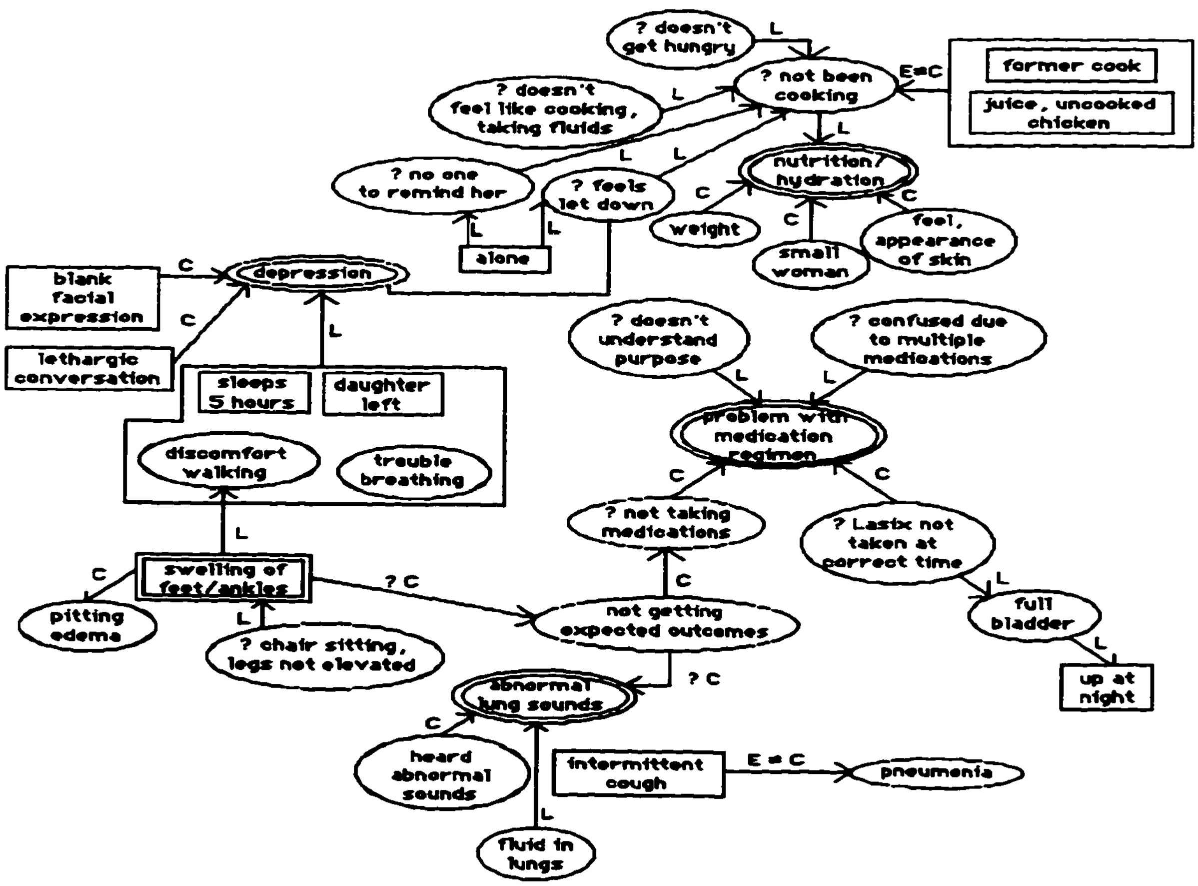


Figure 2. Expert's conceptual graph structure



Results of the pilot test supported some of the predictions. The "expert" demonstrated superior pattern recognition by identifying a greater number of correct problems related to the primary concepts (three) than the "novice" (one partially correct). The "expert" identified only signs and symptoms relating to the underlying condition of CHF as problems, not CHF itself, reflecting only a superficial understanding of this concept. The "novice" identified two problems that were not related to the primary concepts.

Neither participant identified problems that had the potential to occur. However, the "expert" noted many more causal relationships associated with the occurring problems that were identified than did the "novice." In fact, a greater proportion of the "expert's" links were causal (61%) than were characteristic (36%), demonstrating that this participant developed a representation of the problem significantly based on causal associations. In comparison, the "novice's" representation was based on a greater proportion of characteristic links (59%), and much less on causal associations (8%). Thirty-three percent of the "novice's" associations in the problem representation could not be identified as either characteristic or causal.

The "expert" made more correct inferences during problem representation, both characteristic and causal, than the "novice." While none of the "expert's" inferences were incorrect, four of the "novice's" inferences were clearly erroneous and could not be supported from information in the patient scenario. In addition, the "expert's" representation was more cohesive (3.6) than the "novice's" representation (2.0).

Knowledge Structures and Problem Representation: Pilot Study Results

Predictions regarding knowledge structures and problem representation were generally supported by data obtained in the pilot test. The prediction model had more accurate predictions than erroneous ones (8 vs 4). Two accurate predictions for the expert were based on prediction of inclusion of primary concepts, while one accurate prediction was based on prediction of exclusion. However, three of the four erroneous predictions were made for the expert. As expected, the model was most accurate in predicting that a primary concept would be excluded from the problem representation of the novice participant (4 of the 5 accurate predictions for the novice).

While the proportion of characteristic to causal relationships noted in the structural knowledge exercise were approximately equal for the novice and expert (about 50-50), the proportion of the novice's causal associations dropped drastically during the problem representation task (only 12%). The proportion of characteristic to causal links remained approximately 50-50 for the expert.

Finally, it did appear that interconnectivity among concepts in the structural knowledge exercise were positively related to cohesion of problem representation. For the "expert" interconnectivity was 6 and cohesion 3.6, while for the "novice" interconnectivity was 4 and cohesion was 2.0.

APPENDIX B

TYPES OF QUESTIONS TO EVALUATE POTENTIAL EXPERT PARTICIPANTS

The following are the types of questions asked of potential participants' supervisors or peers to identify home care nursing expertise. The questions relate solely to potential participants' home care nursing expertise and patient care abilities. Considerations of factors that are extraneous to actual nursing practice such as punctuality, accuracy or timeliness of documentation, efficiency, or relationships with co-workers were NOT included.

1. How would you rate this nurse's knowledge and skill in home care nursing practice?

below average   average   above average   superior

2. How would you rate this nurse's ability to consistently and accurately identify patient problems?

below average   average   above average   superior

3. How would you rate this nurse's level of practice?

novice   average   expert

APPENDIX C

QUESTION ANSWERING TASK TO MEASURE STRUCTURAL KNOWLEDGE

<u>Instructions</u>

In this exercise, you will be presented with concepts that are of interest to home health care nurses. I am going to present you with these concepts one at a time, and ask you to answer some questions about each of them. Write everything you can think of about the questions. When you are responding, try to answer as if you were a home care nurse.

Here is an example for you to practice. Consider the concept "decubitus ulcer." Thinking like a home care nurse, answer the questions on this page.

[Hand the participant a sheet of paper with "Decubitus Ulcer" at the top, followed by the questions "What characteristics might patients exhibit that would indicate they have a problem with decubitus ulcers?" and "What are the causes of decubitus ulcers?" When the participant is finished, review the responses to see if the participant appears to understand the exercise. If the participant does not understand, repeat the instructions and provide with another unrelated concept such as COPD or diabetes. If the participant does understand, ask:]

Do you have any questions? Okay, let's start.

[Hand the participant 6 sheets of paper, with a study concept at the top of each one followed by the questions above.]

Congestive Heart Failure

1. What characteristics might patients exhibit that would indicate they have a problem with congestive heart failure?

2. What are the causes of congestive heart failure?

Depression

1. **What characteristics might patients exhibit that would indicate they have a problem with depression?**

2. **What are the causes of depression?**

Impaired Mobility

1. What characteristics might patients exhibit that would indicate they have a problem with impaired mobility?

2. What are the causes of impaired mobility?

Poor Medication Management

1. What characteristics might patients exhibit that would indicate they have a problem with poor medication management?

2. What are the causes of poor medication management?

Falls

1. What characteristics might patients exhibit that would indicate they have a problem with falls?

2. What are the causes of falls?

Poor Nutrition/Hydration

1. What characteristics might patients exhibit that would indicate they have a problem with poor nutrition/hydration?

2. What are the causes of poor nutrition/hydration?

APPENDIX D

THINK-ALOUD TASK TO MEASURE PROBLEM REPRESENTATION

Instructions

In this exercise, you will be presented with a patient scenario involving a home care patient. You will have a few minutes to read it. When the time is up, hand the scenario back to me. Then I will ask you some questions.

Do you have any questions about what you are supposed to do? Okay, here's the patient scenario.

[After receiving the patient scenario, the participant has three minutes to read it. When the time is up, the participant is asked to return the scenario to the researcher. The researcher hands the participant a piece of blank paper and says:]

Now, thinking like a home care nurse, write out what areas you feel should be addressed.

[When participants are finished, the researcher looks over the list checking for mention of any potential problems. If no potential problems are listed, the researcher asks:]

Are there any other problems you feel might occur if no interventions are instituted?

[The participant is allowed to list more if desired, and these will be marked by the researcher to distinguish them from the problems that were first listed. When the participant's problem list is completed, the researcher turns on a tape recorder and says:]

Now I'm going to ask you some questions about each of the areas you felt the home care nurse should address. Sometimes the questions may sound repetitive. Please bear with it, and answer the best you can. You don't have to write down your answers. You can just say what you're thinking out loud. After I ask a question, say everything that you can think of to answer it. Are you ready?

How do you know she has a problem with [first listed problem]?

[When the participant has finished answering the question, the researcher asks:]

What do you think is causing the problem with [first listed problem]?

[The above questions will be repeated for each problem listed by the participant.]

You are a home health care nurse making a late afternoon visit to Mrs. Edna Murray, a 69 year old thin, slightly hard-of-hearing, white female with a history of CHF. She was discharged from the hospital two weeks ago after her most recent exacerbation of CHF. Mrs. Murray, a widow, lives alone in a two story brick home in the suburb of a large midwestern city. Mrs. Murray's only child, a daughter, lives out of state and has left a week ago to return to her own home after helping Mrs. Murray get settled after leaving the hospital. Mrs. Murray's home is clean although somewhat cluttered with books, magazines, collectables, and mementos on countertops and tables. Mrs. Murray, a former cook for a local "4 Star" restaurant, is sitting on the living room sofa. She is 5 feet 3 inches tall, and weighs 98 pounds. Her facial expression is blank, and she does not smile when speaking with you. Her oral temperature is 99 degrees Fahrenheit, radial pulse is 68 beats per minute, and respirations are 20 per minute with an occasional nonproductive cough. Her blood pressure is 122/64. You ask Mrs. Murray how she has been sleeping. Speaking in a slow, monotonous tone, she tells you she has been sleeping about 5 hours at night, with frequent wakenings. Mrs. Murray has not taken her medications yet, so you check her medication sheet and find that she is taking furosemide (Lasix) 20 mg po Q am, digoxin (Lanoxin) 0.25 mg po Q am, and potassium chloride 20 mEq po Q am. You locate the medications in an upstairs bedroom. You find a clean glass in the kitchen next to a bowl of fresh fruits, find orange juice in the refrigerator behind a package of uncooked chicken, and help Mrs. Murray take her medications. Her skin is warm, dry, and flaky. It remains tented more than 5 seconds after it is pinched. Lung sounds are low pitched and soft throughout all lung fields. Her extremities have full ROM and moderate muscle strength. You notice she uses the support of walls and furniture when ambulating, and her gait is slow.