Association for Information Systems
AIS Electronic Library (AISeL)

AMCIS 2000 Proceedings

Americas Conference on Information Systems (AMCIS)

2000

A Cognitive Comparison of Modeling Behaviors Between Novice and Expert Information Analysts

I-Lin Huang
Langston University, onhua@us.sina.com

James R. Burns
Texas Tech University, odbur@ttacs.ttu.edu

A Cognitive Comparison of Modeling Behaviors Between Novice and Expert Information Analysts

I-Lin Huang, Langston University, (onhua@us.sina.com)
James R. Burns, Texas Tech University, (odbur@ttacs.ttu.edu)

Abstract

Empirical research into the novice-expert differences in information requirement analysis has recognized that the differences in knowledge and in modeling behaviors are the causes of differences in quality of requirement specifications. However, there is no cognitive process model available for explaining the interactions among the three factors: knowledge, modeling behaviors, and the quality of requirement specifications.

On the basis of structure-mapping model of analogy, this article proposes a cognitive process model that views information requirement analysis as a process of conceptual mapping from the base structures (i.e., the knowledge structures of requirement analysis techniques) to the target structures (i.e., the knowledge structures of users' problem statements). Due to the differences in knowledge, novice and expert information analysts use different types of cognitive processes, relation mapping by experts versus object-attribute mapping by novices, to model information requirements. The different cognitive processes lead to different modeling behaviors, and in turn the different modeling behaviors finally result in different qualities of requirement specifications.

On the basis of the cognitive process model, two ways to improve the performance of novice information analysts are suggested: encouraging novice information analysts to think in terms of relations rather than object-attributes and providing domain-specific requirement analysis techniques that are similar to the problem domains in both relations and object-attributes.

Background

In order to improve the quality of requirement specifications, the research in information requirement analysis has been advancing various requirement analysis techniques such as Data Flow Diagrams, Entity-relationship Diagrams, and Object-oriented Diagrams. The contribution of requirement analysis techniques to the improving quality of requirement specifications is significant. Research evidence has shown that information analysts who specify information requirements by model-based reasoning on the basis of requirement analysis techniques can produce more complete solutions than those with partial or no model-based reasoning behavior (Sutcliffe and Maiden, 1992).

However, the most important determinant for the quality of requirement specifications is still the cognitive capabilities of information analysts (Schenk, Vitalari, and Davis, 1998; Sutcliffe and Maiden, 1992). With the help of requirement analysis techniques, expert information analysts can achieve requirement specifications with high quality (Allwood, 1986; Koubek, et al, 1989; Schenk, Vitalari, and Davis, 1998; Vitalari and Dickson, 1983). In contrast, novice information analysts have difficulties in using requirement analysis techniques to identify important concepts of problem statements, resulting in very poor quality of requirement specifications (Batra and Davis, 1992; Batra and Sein; 1994; Sutcliffe and Maiden, 1992).

In order to avoid costly errors in requirement specifications, it is important to accelerate the transition from novice to expert information analysts (Schenk, Vitalari, and Davis, 1998). This requires an understanding of what are the cognitive processes that make expert information analysts better than novice information analysts in information requirement analysis and why. Consequently, the cognitive differences between novice and expert information analysts have become a major concern of the research in information requirement analysis (Maiden and Sutcliffe, 1992; Schenk, Vitalari, and Davis, 1998; Sutcliffe and Maiden, 1992; Vitalari and Dickson, 1983).

In order to understand the cognitive differences between novice and expert information analysts, one stream of research has investigated the differences of knowledge between expert and novice analysts. Empirical evidence shows that richer knowledge and more effective knowledge organization are the qualities of expert information analysts for better performance in information requirement analysis (Adelson and Soloway, 1985; Allwood, 1986; Koubek, et al, 1989; Vessey and Conger, 1993; Vitalari and Dickson, 1983). Another stream of research has focused on the differences of modeling behaviors between novice and expert information analysts. It has been identified that there are at least four characteristics of modeling behaviors differentiating expert from novice information analysts: model-based reasoning, mental simulation, critical testing of hypotheses, and analogical domain knowledge reuse (Adelson and Soloway, 1985; Guindon and Curtis, 1987,1988; Mainden and Sutcliffe, 1992; Schenk, Vitalari, and Davis, 1998; Sutcliffe and Maiden, 1992; Vitalari and Dickson, 1983).

Research Question

It is well recognized that knowledge and modeling behaviors of information analysts are two important determinants for the quality of requirement specifications. However, there is no cognitive process model of information requirement analysis that can explain how the interactions between knowledge and modeling behaviors influence the quality of requirement specifications. Without an adequate cognitive process model that can explicate the relationship among knowledge, modeling behaviors, and the quality of requirement specifications, research studies may miss important interactions among the three factors in viewing and comparing the cognitive processes of information requirement analysis, resulting in erroneous findings and explanations.

In order to provide an adequate basis for the cognitive research in information requirement analysis, this article proposes a cognitive process model of information requirement analysis to explain the interactions between knowledge and modeling behaviors; and to explain how the interactions influence the quality of requirement specifications. On the basis of the structure mapping theory of analogy (Gentner, 1983; Gentner and Markman, 1997), the cognitive process model views information requirement analysis as a process of conceptual mapping from the base structures (i.e., the knowledge structures of requirement analysis techniques) to the target structures (i.e., the knowledge structures of users' problem statements). Due to the differences in knowledge, novice and expert information analysts use different types of cognitive processes, relation mapping by experts versus object-attribute mapping by novices, to model information requirements. The different cognitive processes lead to different modeling behaviors, and in turn the different modeling behaviors finally result in different qualities of requirement specifications.

The rest of this article is organized into four sections. The next section will review the literature on the novice-expert differences in knowledge and modeling behaviors. Then a cognitive process model of information requirement analysis on the basis of the structure mapping model of analogy will be proposed. On the basis of the cognitive process model, the novice-expert differences in information requirement analysis will then be explained. Finally, the conclusion will be made in the final section.

Literature Review

This section will review the cognitive research of novice-expert differences in information requirement analysis. The first part of this section will discuss the relationship between analysts' knowledge and the quality of requirement specifications. The second part will review the novice-expert differences in modeling behaviors.

1 Knowledge for information requirement analysis

The research into the influence of the knowledge of information analysts on the quality of requirement specifications has been conducted in two dimensions: knowledge availability and knowledge organization (Schenk, Vitalari, and Davis, 1998). First, knowledge availability refers to various types of knowledge used in information requirement analysis. Domain knowledge and modeling knowledge have been suggested as determining factors for the modeling performance of information analysts. Domain knowledge is drawn upon by both expert and novice information analysts in specifying information requirements (Vessey and Conger, 1993). While understanding problem statements, information analysts use domain knowledge to mentally simulate a scenario of the system behavior in order to test the adequacy of the requirement specifications, to add assumptions to increase the completeness of the requirements, to test internal and external consistency of the requirements, and to abstract, summarize, select and highlight important information in the problem statements (Guindon, Krasnar, and Curtis, 1987). Without domain knowledge, even expert information analysts can only specify high-level conceptual models without details (Adelson and Soloway, 1985). With the availability of domain knowledge, novice information analysts can reuse the domain knowledge to achieve almost the same level of completeness of requirement specifications as expert information analysts do (Mainden, and Sutcliffe, 1992).

On the other hand, modeling knowledge has long been regarded as an important factor to differentiate expert from novice information analysts. Modeling knowledge can be divided into syntactic and semantic parts (Koubek, et al, 1989). Syntactic knowledge consists of allowable syntax of a specific modeling language. Semantic knowledge, however, consists of modeling principles which are independent of a particular modeling language (Allwood, 1986). Compared to novice information analysts, expert information analysts with richer semantic knowledge can retrieve and apply more relevant modeling principles, make more critical testing of hypotheses, and finally achieve requirement specifications with better quality (Allwood, 1986; Koubek, et al, 1989; Schenk, Vitalari, and Davis, 1998; Vitalari and Dickson, 1983). Modeling knowledge can also be divided into declarative and procedural aspects (Vessey and Conger, 1993). The procedural aspect of a requirement analysis technique is more difficult to learn than the declarative aspect. However, the procedural aspect of modeling knowledge is more important in determining the quality of requirement specifications (Vessey and Coger, 1993).

The second aspect of information analysts' knowledge that is important for the quality of requirement specifications is knowledge organization. Knowledge organization refers to the ways by which the knowledge is stored in the long-term memory of information analysts.

There are basically two features of knowledge organization that can differentiate expert from novice information analysts in information requirement analysis. The first feature is that expert information analysts store their knowledge in bigger units. Because of the bigger chunks of knowledge extracted from experience, experts can automate some aspects of problem solving process while novices use the first principle (Allwood, 1986; Guindon, Krasner, and Curtis, 1987; Guinder and Curtis, 1988). On the other hand, novices store their knowledge in smaller units. As a result, many errors can be caused by novices' inability to map parts of the problem description to appropriate knowledge structures as well as by novices' failure to integrate pieces of information (Allwood, 1986).

The second feature is that expert information analysts use higher-order abstract constructs to organize large amount of knowledge while novice analysts store concrete objects sparsely in the long-term memory. Research evidence shows that experts use richer vocabulary to categorize problem descriptions into standard abstraction. As a result, experts can retrieve knowledge structure easily, and they can focus more on the semantic structure of problems rather than surface or syntactic feature (Allwood, 1986; Koubek, Salvendy, Dunsmore, and Lebold, 1989).

Due to the above two important features of knowledge organization, expert analysts can have better performance in information requirement analysis by (1) processing large amounts of information into meaningful chunks;(2) retrieving the knowledge structures easily; and (3) categorizing problems into standard types based on underlying domain principles (Batra and Davis; 1992).

2 Modeling behaviors

Empirical studies on the modeling behaviors of information analysts show a strong association among the activities of gathering information, identifying relevant facts, and conceptual modeling (Batra and Davis, 1992; Sutcliffe and Maiden, 1992). This strong association reflects that information requirement analysis is basically an understanding process.

To account for the better performance of expert information analysts in understanding and specifying information requirements, four characteristics of the modeling behaviors of expert information analysts have been identified: model-based reasoning, mental simulation, critical testing of hypotheses, and analogical domain knowledge reuse. First, expert information analysts use model-based reasoning to model information requirements with the help of various requirement analysis techniques (Sutcliffe and Maiden, 1992; Vitalari and Dickson, 1983). Research evidence shows that information analysts who use more model-based reasoning produce more complete solution than those with partial or no model based reasoning behavior. On the other hand, research evidence also shows that novice analysts have difficulty in using requirement analysis techniques effectively (Sutcliffe and Maiden, 1992). For example, in a research study on the modeling behaviors of novice information analysts in using Data flow Diagrams, it was shown that the novice information analysts were more successful at recognizing system goals and inputs, while there was poorer recognition of system data stores, processes, and outputs, even though data stores, processes, and outputs were explicitly stated in the problem narrative (Sutcliffe and Maiden, 1992).

The second feature of expert analysts' modeling behaviors is mental simulation. Mental simulation refers to the cognitive processes of building a mental model that establishes connections among the parts of the system under investigation and of using the mental model to reason about the interactions among the parts of the system (Adelson and Soloway, 1985; Guindon, Krasner, and Curtis, 1987; Guinder and Curtis, 1988). During information requirement analysis, expert information analysts use requirement analysis techniques for mental simulation of information requirements while novice analysts used requirement analysis techniques only for representation (Adelson and Soloway, 1985). Mental simulation makes expert analysts focus on the semantic part of the problem statement. On the other hand, without mental simulation novice information analysts can analyze only the syntactic part of the representation (Adelson and Soloway, 1985; Allwood, 1986).

Critical testing of hypotheses is the third feature of the modeling behaviors of expert information analysts. By means of mental simulation, expert information analysts can have a clear picture about the structure of the information requirements (Guindon, Krasner, and Curtis, 1987; Guinder and Curtis, 1988). Consequently, experts may be more able to reason about a problem, to create test cases and scenarios for testing hypotheses critically (Schenk, Vitalari, and Davis, 1998; Vitalari and Dickson, 1983). On the other hand, novice information analysts can generate hypotheses only at a general level and make few attempts to test hypotheses because they focus only on the syntactic part of the representation (Schenk, Vitalari, and Davis, 1998).

Finally, analogical domain knowledge reuse makes expert information analysts able to specify information requirements more completely and accurately (Mainden and Sutcliffe, 1992). Expert information analysts tend to use higher-order abstract constructs to organize large amount of knowledge. As a result, expert information analysts can recognize and assimilate analogies more easily (Batra and Davis; 1992; Vitalari and Dickson, 1983). In addition, expert information analysts tend to keep in memory the details of requirement specifications from their past experience. Consequently, higher quality can be expected because the reused specifications are well tested and validated. On the other hand, novice information analysts have difficulties in identifying the opportunities of analogical modeling because they tend to store concrete objects sparsely in the long-term memory (Batra and Davis; 1992; Sutcliffe and Maiden; 1992). In addition, novice information analysts tend to specify information requirements from the first principle because of the lack of reusable specifications in their memory (Vitalari and Dickson, 1983).

A Cognitive Process Model of Information Requirement Analysis

Information requirement analysis has been recognized as a process of understanding the contexts of information systems and then specifying the information requirements for the information systems (Borgida, Greenspan, and Mylopoulos, 1985; Fraser, Kumar, and Vaishnavi, 1991). From the perspective of human cognition, understanding is a process of building a coherent mental representation of the information being comprehended (Gernsbacher, 1990; Graesser, 1995; Kintsch, 1988). On the basis of the structure mapping model of analogy (Gentner, 1983; Gentner and Markman, 1997), this article proposes a cognitive process model of information requirement analysis to explicate the modeling behaviors of information analysts as shown in Figure 1. This section will discuss the mechanism of this cognitive process model. The strength of the model that can explain the differences of modeling behaviors between novice and expert information analysts will be discussed in the next section.

In this section, we will assume a requirement sentence, “The customer first sends an order to John, the order clerk”, in a problem statement of an order processing system as an example to illustrate the cognitive process of information requirement modeling.

On the basis of the structure mapping model of analogy, the cognitive process of information requirement analysis can be divided into three parts: parsing, modeling, and questioning as follows:

1. Parsing:

A problem statement is the source of target structures that includes concepts and structures of information requirements. The task of information requirement analysis is to construct a model that can connect the concepts and structures of the problem statement into a coherent whole. If a coherent model can be built for the problem statement, then the task of understanding the problem statement is achieved.

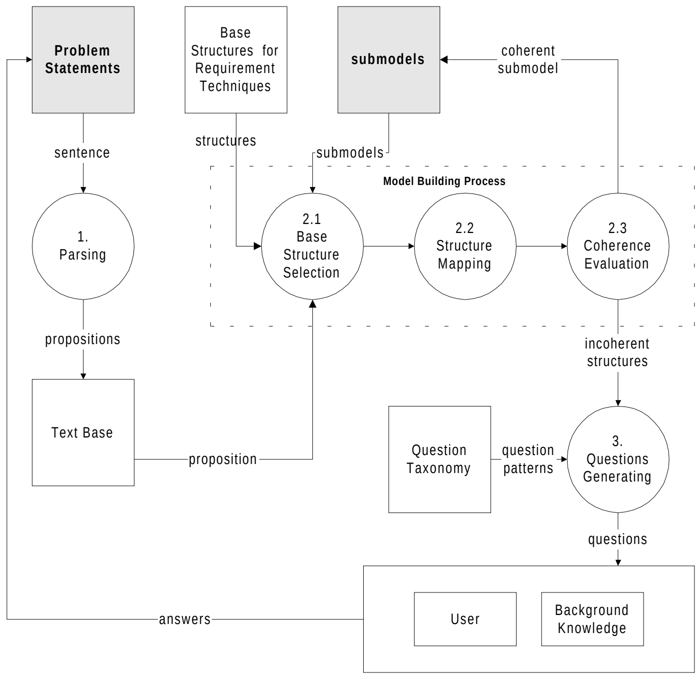
Parsing as the first step in modeling translates the example sentence into a target structure in the form of propositional knowledge like below (Kintsch, 1974):
send (CUSTOMER, ORDER, ORDER CLERK)
send : predicate; CUSTOMER: agent; ORDER: object; and ORDER CLERK: agent.

The translation depends mainly on analysts’ knowledge about natural language (in this case, English). In this article, we assume that both novice and expert information analysts have the same level of ability to understand English text. Thus, we can assume that both novice and expert information analysts can come up with a piece of propositional knowledge similar to the above one.

2. Modeling:

Modeling is the process that translates the received target structure into the form of a base structure of a particular requirement analysis technique. In this article, we assume that the selected requirement analysis technique is Data Flow Diagrams. On the basis of the structure mapping model, the modeling process can be divided into three subprocesses: selecting, mapping and evaluating as follows.

Figure 1: A cognitive process model of information requirement analysis



2.1 Selecting a base structure.

In order to specify the information requirements in the problem statement by a particular requirement analysis technique, information analysts access the base structures of the requirement analysis technique to match the incoming target structure. Basically, there are two factors determining which base structure will be selected: the principle of continuity (Zwaan, Graesser, and Magliano, 1995) and the types of similarity (Gentner, 1983). First, on the basis of the principle of continuity, information analysts tend to access the base structure that can be connected to the submodels that have been built so far, especially the most recent one. This principle reflects that information analysts try to build a connected and coherent model for the whole problem statement.

Second, there are four types of similarity between target and base structures that can trigger the access of a particular base structure (Gentner, 1983): literal similarity, analogy, abstraction, and surface similarity. Literal similarity is a comparison in which a base structure can be mapped onto the target structure with both object-attribute and relational (or called structural) predicates (e.g., The order processing system is like that of company X I analyzed last year.). Analogy is a comparison in which relational predicates, but few or no object attributes, can be mapped from base to target (e.g., The order processing system is like the library system I analyzed two years ago.). Abstraction is a comparison in which the base structure is an abstraction of the target structure (e.g., I want to use the base structure, inflow (external entity, dataflow, process), from Data Flow Diagrams to model the target structure). And finally, surface similarity is a comparison in which the base structure shares similar objects and attributes with the target structure (e.g., I want to model customer as external entity, and order as data store).

Empirical evidence shows that human knowledge is easier to learn and hence to be organized by object-attribute similarity, rather than by structural similarity. Thus, novice information analysts tend to access base structures by literal similarity or surface similarity because both have the feature of object-attribute similarity. Abstraction and analogy are rarely used by novice information analysts to access base structures because the structural similarity is more difficult to identify.

On the other hand, expert information analysts have learned from experience that structural similarity (or even higher-order structure similarity) has better explanation power than object-attribute similarity. Therefore, expert information analysts will prefer abstraction and analogy to surface similarity in selecting base structures. Empirical evidence shows that experts learn from experience to organize their knowledge by abstract relations rather than objects or attributes (Halford, 1987).

For illustration, if the information analysts decide to use Data flow diagrams to model the example sentence mentioned above, the expert information analysts may select a higher-order relational base structure like inflow (external entity, data flow, process). On the other hand, novice information analysts may select a object-attribute base structure like external entity , data store, and external entity to match the three concepts in the problem statement: CUSTOMER, ORDER, and ORDER CLERK, regardless of the potential relations among the three concepts.

2.2. Mapping the base structure onto the target structure

While mapping the base structure onto the target structure, a higher-order relation (or predicate) will be more likely to be imported into the target structure than is an isolated relation or object-attribute. It is called the principle of systematicity (Gentner and Markman, 1997). For example, if the selected based structure is inflow(external entity, data flow, process), then the information analyst will be able to get the following three results on the basis of model-based reasoning:

(1) CUSTOMER will be mapped as external entity, and ORDER as data flow;

(2) ORDER CLERK cannot be mapped as process. The information analyst may therefore make inferences to decide that the process is what the order clerk does---order processing; and

(3) The information analyst may find out by abstraction that the requirement “customer first sends an order to the order clerk” is an input data flow for a high-order structure---an order processing system. On the basis of the principle of systematicity, the information analyst may try to model the whole order processing system by identifying data stores and output data flows from his or her domain knowledge.

2.3. Evaluating the submodel

The result submodel will finally be evaluated on the basis of coherence. For example, by using the base structure, inflow (external entity, date flow, process), to match the requirement sentence, send(CUSTOMER, ORDER, ORDER CLERK), we will find ORDER CLERK can not be matched by process because ORDER CLERK is obviously an agent rather than a process. If the information analyst cannot identify “processing order” as the process by model-based reasoning, then the mismatch between ORDER CLERK and “process” will cause an incoherence. Consequently, the information analyst may decide to abandon the mapping and try another base structure; or he may choose to keep it and solve the incoherence later.

3. Asking questions about the incoherences in the submodel

The incoherences in submodels will become the cues for questioning. For example, in order to erase the incoherence on the mismatch between ORDER CLERK and “process”, information analysts may ask questions to identify the missing process in the submodel. Example question may be like: What task is done by the order clerk? Or more directly, what is the process for the incoming order?

An Explanation for the Novice-Expert Differences

The purpose of the cognitive process model of information requirement analysis is to describe the cognitive processes of the modeling behaviors of information analysts. The strength of the cognitive process model is its ability to explain how knowledge is related to the four characteristics of modeling behaviors that differentiate expert from novice information analysts: model-based reasoning, mental simulation, critical testing of hypotheses, and analogical domain knowledge reuse. First, the differences between expert and novice information analysts in model-based reasoning. Expert information analysts organize their knowledge by abstract relations. Thus, expert information analysts tend to access base structures for modeling target structures on the basis of relational similarity. Consequently, expert information analysts can use model-based reasoning more effectively because they can get richer explanation power from the relational base structures. On the other hand, novice information analysts organize their knowledge as concrete objects sparsely in the long-term memory. Thus, they select base structures on the basis of object-attribute similarity that give limited explanation power for modeling the target structures. As a result, novice information analysts have difficulty in making meaningful inferences from the base structures.

Second, the differences in mental simulation. Expert information analysts can use requirement analysis techniques as a basis for mental simulation because the base structures they choose reflect the relations among concepts in the target structures. On the other hand, novice information analysts can use requirement analysis techniques only for representation because the base structures they choose reflect only the object-attributes of the target structures.

Third, the differences in hypothesis testing. On the basis of mental simulation, expert information analysts can make critical testing of hypotheses on the basis of the principle of continuity. Without mental simulation, novice information analysts can generate hypotheses only at a general level and make few attempts to test hypotheses.

Finally, the differences in analogical reasoning. On the basis of the principle of systematicity, expert information analysts can identify opportunities of analogical reasoning more easily because they use abstract concepts to organize their knowledge. In addition, expert information analysts can reuse specifications in bigger units and with higher quality because they store in memory the details of the well tested and validated specifications from their past analysis experience. On the contrary, novice information analysts have difficulties in identifying analogies because they focus on concrete objects and attributes. As a result, they often need to develop requirement specifications on the basis of the first principle.

Conclusion

On the basis of the structure-mapping model of analogy, this article has proposed a cognitive process model of information requirement analysis to explain the interactions between knowledge and modeling behaviors, and to explain how the interactions influence the quality of requirement specifications. It is shown that different cognitive processes lead to different modeling behaviors and different modeling behaviors in turn result in different qualities of requirement specifications.

In this article, it is suggested that the most basic reason accounting for the different performances between novice and expert information analysts is that novice and expert information analysts pay attention to different aspects of a problem statement: Experts focus on the relational side of the problem statement but novices on the object-attribute side. Therefore, at least two implications can be identified in this research: First, in order to accelerate the transition from novice to expert information analysts, novice information analysts should be encouraged to learn and to think in terms of relations rather than of object-attributes. Actually, thinking in terms of relations has also been suggested as an effective way to improve students' reading comprehension (Nix, 85). Second, novice information analysts can have the same level of performance as expert information analysts have if the target and the base structures share literal similarity that includes both relational and object-attribute similarities. Therefore, domain-specific requirement analysis techniques deserve future research because they use the same concepts and structures as those of the problem statements and hence will improve the productivity of novice information analysts significantly.

References

Adelson, B., and Soloway, E. "The Role of Domain Experience in Software Design," IEEE Transactions On Software Engineering, se-11 (11), 1985, pp. 1351-1360.

Allwood, C. M. "Novices on the Computer: A Review of the Literature," International Journal of Man-Machine Studies, (25), 1986, pp. 633-658.

Batra, D., and Davis, J. G. "Conceptual Data Modeling in Database Design: Similarities and Differences Between Expert and Novice Designers," International Journal of Man-Machine Studies, (37), 1992, pp. 83-101.

Batra, D., and Sein, M. K. "Improving Conceptual Database Design Through Feedback," International Journal of Human-Computer Studies, (40), 1994, pp. 653-676.

Borgida, A., Greenspan, S., & Mylopoulos, J. "Knowledge Representation as the Basis for Requirements Specifications," IEEE Computer, April 1985, pp. 82-90.

Dardenne, A., van Lamsweerde, A., and Fickas, S. "Goal-Directed Requirements Acquisition," Science of Computer Programming, (20), 1993, pp. 3-50.

Davis, A. M. "A Comparison Of Techniques For The Specification Of External System Behavior," Communications of the ACM, (31:9), 1988, pp. 1098-1115.

Dorfman, M. "System and Software Requirements Engineering," in System and Software Requirements Engineering, Thayer, R. H., and Dorfman, M. (eds.). IEEE Computer Society Press, 1990, pp. 4-16.

Fraser, M. D., Kumar, K., and Vaishnavi, V. K. “Informal and Formal Requirements Specification Languages: Bridging the gap,” IEEE Transaction On Software Engineering, (17:5), 1991, pp. 454-465.

Gentner, D. “Structure-Mapping: A Theoretical Framework for Analogy,” Cognitive Science, (7), 1983), pp. 155-170.

Gentner, D., and Markman, A. B. “Structure Mapping in Analogy and Similarity,” American Psychologist, (52:1), 1997, pp. 45-56.

Gernsbacher, M. A. Language Comprehension as Structure Building. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.,1990.

Graesser, A. C. “Inference Generation and the Construction of Situation Models,” in Discourse Comprehension, Weaver, C. A., Mannes, S. , and Hetcher , C. R. (eds.). Hillsdale New Jersey: Lawrence Erbaum Associates, Publishers, 1995, pp. 117-139.

Greenspan, S. J., and Mylopoulos, J. “Capturing More World Knowledge in the Requirements Specification,” Proceedings of International Conference in Software Engineering, IEEE Computer Society Press, 1982, pp. 225-234.

Guindon, R., and Curtis, B. “Control of Cognitive Process During Software Design: What Tools Are Needed?” Proceedings of CHI’88, 1988, pp. 263-268.

Guindon, R., Krasner, H., and Curtis, B. “Cognitive Process in Software Design: Activities In Early, Upstream Design,” in Human-computer Interaction-INTERACT’97, Bullinger, H. J., and Shackel, B. (eds), North-Holland, 1987, pp. 383-388.

Halford, G. S. “A Structure-Mapping Approach to Cognitive Development,” International Journal of Psychology, (22), 1987, pp. 609-642.

Kintsch, W. The Representation of Meaning in Memory Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers, 1974.

Kintsch, W. “The Role of Knowledge in Discourse Comprehension: A Construction-Integration Model” Psychological Review, (95:2), 1989, pp. 163-182.

Koubek, R. J., Salvendy, G., Dunsmor, H. E., and Lebold, W. K. “Cognitive Issues in the Process of Software Development: Review and Reappraisal,” International Journal of Man-Machine Studies, (30), 1989, pp. 171-191.

Mainden, N. A., and Sutcliffe, A. G. “Exploiting Reusable Specifications Through Analogy.,” Communication of The ACM, (35:4), 1992, pp. 55-64.

Nix, D. H. “Notes on the Efficacy of Questioning,” in The Psychology of Questions Graesser, A. C. and Black, J. B. (eds.), Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers, 1985, pp. 297-333.

Roman, G. “A Taxonomy of Current Issues in Requirements Engineering,” IEEE Computer, April 1985, pp. 14-22.

Scharer, L. “Pinpointing Requirements,” Datamation, April 1981, pp. 17-22.

Schenk, K. D., Vitalari, N. P., and Davis, K. S. “Differences Between Novice and Expert System Analysts: What Do We Know and What Do We Do?” Journal of Management Information Systems, (15:1), 1998, pp. 9-50.

Shemer, I. “System Analysis: A Systematic Analysis of a Conceptual Model,” Communications of the ACM, (30:6), 1987, pp. 506-512.

Sutcliffe, A., and Maiden, N. “Analysing the Novice Analyst: Cognitive Model in Software Engineering.,” International Journal of Man-Machine Studies, (36), 1992, pp. 719-740.

Vessey, I., and Conger, S. “Learning to Specify Information Requirements: The Relationship Between Application and Methodology,” Journal of Management Information Systems, (10:2), 1993, pp. 177-201.

Vessey, I. And Conger, S. A. “Requirement Specification: Learning Object, Process, and Data Methodologies.,” Communications of the ACM, (37:5), 1994, pp. 102-113.

Vitalari, N. P., and Dickson, G. W. “Problem Solving for Effective System Analysis: An Experimental Exploration,” Communications of the ACM, (26:11), 1983, pp. 948-956.

Zwaan, R. A., Graesser, A. C., and Magliano, J. P. “Dimensions Of Situation Model Construction in Narrative Comprehension,” Journal of Experimental Psychology, (21:2), 1995, pp. 386-397.