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A Cognitive Model of Knowledge Transformation in Authoring Hypertext

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A COGNITIVE MODEL OF KNOWLEDGE TRANSFORMATION IN
AUTHORING HYPERTEXT

BY

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ABSTRACT

The primary purpose of this study was to propose a grounded theory of knowledge transformation in the hypertext authoring process. More specifically, the present study attempted to answer the following two questions: 1) what cognitive processes are involved in knowledge transformation through hypertext authoring and 2) how are these cognitive processes interrelated. For the first question, this study identified cognitive components associated with the knowledge transformation. For the second question, this study explained how the cognitive components interact within a theoretical framework of knowledge transformation.

This study was an inquiry-oriented research to investigate how learners transform their prior knowledge and what cognitive processes are occurring during the hypertext authoring process. Specifically, this study endeavored to construct a cognitive model of knowledge transformation by identifying what cognitive components constitute the knowledge transformation process and how they are structured as a model. Since there has been no systematic scrutiny of the cognitive processes of knowledge transformation in authoring hypertext, an inductive data analysis, a qualitative research method, is employed to theorize a cognitive model of how and/or what cognitive processes are occurring. This study set three stages to elaborate data collection methods and delineate the cognitive process of knowledge transformation in authoring hypertext: 1) Model Initiation Stage, 2) Model Elaboration Stage, and 3) Model Theorization Stage. These three stages compose the iterative model saturation process of this study, which was based on not only iterative data analysis and comparative analysis but also an evolutionary design approach.
For the Model Initiation Stage, one Korean graduate student, who was majoring in instructional systems and enrolling in a southeast public university, participated to the initial stage. The purpose of the Model Initiation Stage was to build a preliminary model of knowledge transformation in authoring hypertext. The results of Model Initiation Stage revealed that there were two factors as causal conditions that determine the participant’s cognitive process. As a second cognitive component, it was observed that the participant was prioritizing key concepts to transform his prior knowledge. For a third cognitive component, it was identified that the functions of authoring tool regulated the participant’s cognitive process.

The Model Elaboration Stage was directed by the findings from the Model Initial Model. Three Korean graduate students, who were majoring in instructional systems and enrolling in a southeast public university, participated in the Model Elaboration Stage. Five cognitive components were identified: 1) content knowledge, 2) causal condition, 3) internal modification of knowledge structure, 4) external representation by tool regulations, and 5) instructional knowledge.

Finally, for the Model Theorization Stage six Korean graduate students participated. The outcome of the Model Theorization Stage identified six cognitive components and their relationships during knowledge transformation through an authoring tool: authoring goal, 2) content knowledge, 3) instructional knowledge, 4) preliminary modification of knowledge structure, 5) external representation by tool regulation, and 6) internal modification of the knowledge structure.

Authoring goal was identified as to activate content knowledge and instructional knowledge. When participants were given the authoring goal, it activated what domain knowledge should be used for the content knowledge and how the knowledge should be organized for the instructional knowledge. Content knowledge played a role as a main resource to be transformed. Instructional knowledge was identified to an effect at an earlier stage of the knowledge transformation process. Both of content knowledge and instructional knowledge were coordinating for the preliminary modification of knowledge structure. After the authoring goal activated their content knowledge and
instructional knowledge, participants were observed to begin to modify their knowledge structure for transformation. Yet, there was no mediation by the functions of an authoring tool, the modification of knowledge structure needed to remain a preliminary form of knowledge transformation. The main features of this preliminary modification of the participants’ knowledge structure occurred as the following sequence: 1) comprehension of the concepts, 2) adjustment of the participants’ prior knowledge of the concepts, and 3) configuration of the interrelationships of the concepts. External representation by tool regulation was identified to mediate the process of knowledge transformation. In order to externalize the modified mental representation, participants had to follow the authoring tool’s functions. Consequently, the changed mental representation needed to be altered by the ways an authoring tool allowed the presenting of knowledge. Then, finally, participants could complete internal modification of their knowledge structure with working together with the external representation by tool regulation.

The results of this study proposed that there were two different types of knowledge searching process during the knowledge transformation through an authoring tool: 1) concept level knowledge searching process and 2) structure level knowledge searching process. Whereas the concept level searching process is employed for a conceptual understanding, the structure level searching process is used to understand the interconnectedness of concepts. The concept level searching process is activated at the moment a concept is understood, and the process is spread out through very limited numbers nodes of semantic networks. Thus, the knowledge searching process is limited node-by-node. On the other hand, the structure level knowledge searching process is activated to scan interrelationships among concepts, and the process is spread out across the chunks of semantic networks that consist of a set of nodes.
CHAPTER 1
INTRODUCTION

Background

John Dewey’s theory of experiential learning, also known as learning by doing, is one of the most influential learning theories. For Dewey, it was vitally important that learners be fully integrated into the learning experience rather than be introduced to a bulk of knowledge and a skill set. By providing a direct participation, the learner is actively engaged in the learning process. The essence of this theory is found in this widely quoted Chinese saying, “What I hear, I forgot; what I see, I remember; what I do, I understand.” From this perspective, learning is not a process of transmitting information from a teacher to a learner; rather, learning is an active process where knowledge and understanding are constructed by the learner (Soloway & Bielaczyc, 1995).

Unfortunately, Dewey’s concept of learning continues to challenge most educators. Schools rarely have adopted this learning by doing theory, in part because the philosophy of learning in schools is often one of knowledge transmission rather than of knowledge construction (Lehrer, Erickson, & Connell, 1994). School curriculum does not always provide for students to learn by doing but, rather, requires them to memorize information about the theory of the task without concentrating on the doing of the task (Schank & Cleary, 1995). As a result, the conventional school system often leads students to the acquisition of “inert” knowledge, encapsulated information that is rarely accessed again unless a specific use for activation is given (Bereiter & Scardamalia, 1989; Brown...
This problem of creating “inert knowledge” by imparting factual knowledge is that learners are not learning how to use the knowledge when they need to apply it (Schank, Berman, & Macpherson, 1999). Since this problem has been raised, the efforts to reduce “inert knowledge” have been a central focus of school reform. The issues of school reform have been constantly forcing educators to seek innovative methods to enhance educational practices. There have been continuous efforts to utilize computers to improve instruction and learning as a part of school reform. The effort of integrating computers into learning has resulted in positive effects and a great deal of change for contemporary school systems, though the use of the computer has not always yielded better achievements than those produced by conventional teaching methods. Thousands of studies related to computers and learning have been conducted during the past three decades (Hannafin, Hannafin, Hopper, Reiber, & Kini, 1996). With this continuous evolutionary effort to use computers, computer capabilities and design strategies have expanded so that using computers in education has become more interactive and effective. The expanded use of computers in learning has occurred as an interactive byproduct of ongoing developments in psychology. Specifically, cognitive psychology has made considerable contributions toward developing better solutions for the use of computers in education. For instance, the use of computers in education has shifted toward design principles to assist the learner in selecting appropriate information, organizing information into internally consistent concepts, and integrating new with existing knowledge. The result is a personally relevant and meaningful learning experience (Hannafin et al., 1996).

Along with this shift, a new perspective of designing and utilizing computers for pedagogical purposes has been shaped using computers as cognitive tools. This perspective has made a distinction between learning from computers and learning with computers (Jonassen & Carr, 2000; Jonassen & Reeves, 1996; Liu & Rutledge, 1997). The main idea of using the computer as a cognitive tool is that the technology can enhance the cognitive powers of thinking, problem solving, and learning for the learners. With these cognitive tools, information is not stored in a predetermined manner to be
transmitted to learners. Rather, learners themselves interact with the computer as a means to analyze the world, access information, interpret and organize their personal knowledge, and represent what they know to others (Jonassen & Reeves, 1996).

For instance, when learners use a database program to build a data set, they need to develop the data structure, locate relevant information, and manipulate the information to merge it into another cell or field. Through these activities, the learners will be able to use higher cognitive skills to analyze, evaluate, and synthesize information (Jonassen & Carr, 2000). For another example of a cognitive tool, LOGO would be the most cited example to show how learners can improve their cognitive power by interacting with computers. LOGO is a simplified computer programming language developed by Seymour Papert (1980) specifically for children. Basically, it was invented to help children understand geometrical and mathematical concepts. The children can move a turtle-like object by programming the computer. For instance, they can program the turtle on the screen to draw a triangle. To make a proper movement to draw a triangle the learners predict and test if their programming was correct. Through LOGO, a learner acts like a designer to actively accomplish his or her intended goal. The idea of this learning environment was to give the learners opportunities to construct knowledge using their own design process. As a result, the interaction between the learners and the computer helps users construct deeper knowledge of the learning domain and become active learners (Jonassen & Carr, 2000; Jonassen & Reeves, 1996). The idea of LOGO introduced a computerized implementation of learning by designing.

Another stage in the evolution of using computers in education came in the early nineties as hypertext, also referred to as hypermedia, emerged to support learning. Hypertext is a type of computer application consisting of links between information so that a learner can browse the learning content like a Web-browser of today (Nelson & Palumbo, 1992). Hypertext and hypermedia applications consist basically of the same architecture that allows learners to follow the content, except that hypertext is built with only text while hypermedia contains multimedia properties. A conventional computer based instruction (CBI) is designed to provide learners a linear sequence to instruct new
knowledge and/or skills. Thus, it is designed in linear ways. By contrast, hypertext allows learners to browse any screen to discover knowledge similar to surfing the Internet. In hypertext, each knowledge segment is defined as a node, and a learner’s browsing path is referred to as a link to connect nodes (Nelson & Palumbo, 1992). The free navigation through the knowledge architecture of the hypertext system enables learners to interact more with the computer than does a conventional CBI. Users visit one node to learn the knowledge in it and can move to another node linked to the node they are currently visiting. Hypermedia shares these characteristics of hypertext and additionally includes multimedia features of interactive video, providing multiple representations of information through the use of sound and animation (Liao, 1999).

A key benefit of hypertext/hypermedia is that it enables learners to freely navigate the knowledge architecture of hypertext/hypermedia wherever they want to visit. Therefore, the learners will navigate the knowledge structure of hypertext/hypermedia system in non-linear ways. It is assumed the free navigation within hypertext/hypermedia system represents the learner’s information seeking process. In other words, navigation paths indicate where an idea is followed using the links in the hypertext/hypermedia system (McAleese, 1989). For this reason, non-linearity of navigation is one of the most distinctive features of hypertext/hypermedia in that learners can select their learning paths through hypertext/hypermedia rather than follow the predetermined sequence of the conventional CBI program.

During the learner’s navigation, his or her memory structure is being formed by the learner’s knowledge seeking process in hypertext/hypermedia. Therefore, the navigation represents semantic structure that mirror some of the associational powers of human memory during learning (Nelson & Palumbo, 1992). It is essential that navigation of the hypertext/hypermedia structure parallel the function of human memory. The non-linear navigation allows learners to network their own knowledge structure and associate links of information. The networks and links represent the learners’ semantic memory as constructed by them. This feature of hypertext/hypermedia corresponds to the nature of human memory, which relies not upon the storage or retrieval of specific units of
knowledge but, rather, on the association of schemes (Nelson & Palumbo, 1992). The associational knowledge construction process is very similar to learning by doing in which the learner organizes his or her knowledge. By having one’s own knowledge organization, the learner will be able to increase the flexibility of applying his or her knowledge. Nonlinearity in hypertext/hypermedia supports the learners’ cognitive flexibility by allowing interaction with the computer. Nonlinearity helps promote deep conceptual understanding and the ability to apply acquired knowledge in a new situation (Jacobson, 1994; Spiro, Feltovich, Jones, & Coulson, 1992). Because of its non-linear, flexible, and associative characteristics, hypertext/hypermedia can provide more intensive interactivity between learners and the hypertext/hypermedia. In other words, learners will learn by linking knowledge, in essence designing or webbing their own knowledge. This feature corresponds to the idea of LOGO, where learners constructed deeper knowledge by interacting with the computer.

**Context of the Study**

The idea behind hypertext/hypermedia cognitive tools is that better learning will not come from following a sequence predetermined by a teacher but from giving the learner opportunities to construct knowledge. With the advantages of hypertext/hypermedia, there has been an extended application of hypertext/hypermedia as a cognitive tool. Use of hypertext/hypermedia cognitive tools, also known as learning by authoring, enables learning to occur as hypertext/hypermedia products are developed by a learner. Learning by authoring hypertext/hypermedia allows learners as authors to create their own hypermedia documents. As authors, learners have opportunities to be creative and actively pursue their own learning goals. In this concept of learning by authoring hypermedia, learners are engaged in a meaningful task when constructing knowledge. When learners are involved in the production of interactive hypermedia texts, they are
focused on learning throughout the authoring process while they actively explore learning resources (Lockyer & Kerr, 2000).

Studies in learning by hypermedia authoring reveal the advantage of using hypermedia authoring as an instructional method. Learners who used hypermedia authoring outperformed those in a control group when articulating and defending essay topics (Spoehr, 1993). Using hypertext/hypermedia, learners’ problem solving skills increased and became more complex, and as a result, their understanding became more sophisticated (Oughton & Reed, 1998). A similar result was reported in that learners showed frequent use of higher order thinking such as finding, interpreting, and articulating knowledge structure (Lehrer et al., 1994). Having learners develop hypertext/hypermedia documents, rather than using the computer merely to receive knowledge, allowed the learners to use higher order thinking skills and complex problem-solving skills with more cognitive efforts (Oughton & Reed, 1998).

Studies in learning by authoring hypermedia have reported that learners become active learning partners instead of being simply receptive learners (Liu & Rutledge, 1997). Placing learners as multimedia authors affords them opportunities to acquire higher-order thinking skills and to develop complex skills (J. Erickson & Lehrer, 1998, 2000; Lehrer, 1993; Lehrer et al., 1994). The studies have shown positive results that hypermedia authoring helps learners to develop elaborated knowledge structures and improve problem-solving skills. When learners develop hypermedia products, they have to transform their knowledge into the multimedia products they create. During the transformation, considerable cognitive processing is involved through assembling, connecting, and organizing knowledge (Nicaise & Crane, 1999). With these cognitive strategies, hypermedia authoring enhances the learners’ performance. Although some studies have identified the learning of thinking skills through hypermedia authoring (Carver, Lehrer, Connell, & Erickson, 1992; Lehrer, 1993; Lehrer et al., 1994; Liu, Jones, & Hemstreet, 1998; Liu & Rutledge, 1997), there are very few studies developing a cognitive model to investigate how these cognitive strategies/skills affect knowledge transformation and when these skills are used. It seems likely that cognitive efforts to
transform knowledge into hypermedia products could play a significant role in improving performance. Thus, it would be important to identify what cognitive strategies are used during knowledge transformation and how and when learners use them. The present study attempts to develop a cognitive model of knowledge transformation in hypermedia authoring.

**Research Questions**

Before proposing the research questions for this study, it is necessary to define what knowledge transformation through an authoring tool is. This helps to clarify what questions should be asked in order to develop a model for cognitive processes involved in knowledge transformation. For this study, knowledge transformation through an authoring tool is defined as stated below:

*Knowledge transformation through an authoring tool comprises the mental activities and processes associated with interaction with an authoring tool to refine and relocate prior knowledge to develop and create meaningful knowledge artifacts in the form of computerized document to solve a given problem.*

In this definition three aspects are involved. First, internal modification of prior knowledge should take place. This aspect corresponds to “mental activities and processes of refining and relocating prior knowledge” in the definition. Knowledge transformation is a process of restructuring existing knowledge, and internal modification refers to the process of refining and relocating knowledge. Second, externalization of the modified mental structure should be followed through the authoring process. This corresponds to “develop and create meaningful knowledge artifacts” of the definition. Once prior
knowledge is internally modified, it then should be externalized as artifacts through an authoring tool. The artifacts should reflect mental representation of the internally modified knowledge structure. Third, a goal to transform prior knowledge should be given. This corresponds to “to solve a given problem” in the definition. The goal plays a role of deciding the direction of knowledge transformation. Appropriateness of the transformed knowledge is evaluated depending upon how well it meets the given goal.

With the given three aspects of the definition, this study focuses on how learners restructure and externalize their prior knowledge through the authoring process rather than attempt to explain how learners acquire new knowledge through the authoring process. Also, the present study does not include multimedia aspects in authoring such as video, graphics, audio, and so on. Rather this study focuses on hypertext as a way to understand a learner’s cognitive process. Excluding multimedia features of an authoring tool was a trade-off between the explanation power and the feasibility of the study. If the multimedia features are included in the scope of this study, it may increase the power to illustrate what cognitive processes normally take place when learners use authoring tools that have multimedia functions. However, at the same time, it might decrease the feasibility of conducting this study and delineating conclusions because of the complexity of variables from multimedia functions. Using multimedia functions requires high cognitive skills and load in the authoring process, and there are wide ranges of mastery levels of using the functions for learners. These features of using multimedia functions might be beyond the manageable scope of conducting this study. Therefore, this study focuses on the cognitive process of knowledge transformation without using multimedia functions. This study employs a text-based authoring tool to develop hypertext products.

The primary purpose of this study is to present a grounded theory of knowledge transformation in the hypertext authoring process. More specifically, the present study attempts to answer the following two questions: 1) what cognitive processes are involved in knowledge transformation through hypertext authoring?, and 2) how are these cognitive processes interrelated? For the first question, this study identifies cognitive components associated with the knowledge transformation. For the second question, this
study explains how the cognitive components interact within a theoretical framework of knowledge transformation.

Significance of the Study

Due to a lack of existing cognitive models in authoring hypertext/hypermedia, how learners are authoring/organizing their knowledge into a computerized artifact is not well understood. For instance, it is not known what instructional strategies should be provided when teachers want to apply learning by authoring hypertext/hypermedia to their students’ lessons. Most studies of learning by authoring hypertext/hypermedia have been conducted to verify the effectiveness of applying it as an instructional method. However, very few studies have focused on the general nature of the authoring process.

Studies in hypertext/hypermedia authoring can be categorized into two different approaches. First, the instructional approach focuses on how to effectively guide learners in hypermedia authoring. The researchers in this perspective suggest four steps to support both instructors and learners in the hypermedia authoring environment. In contrast to the instructional approach, the descriptive approach focuses on exploring what kinds of cognitive strategies learners are using in the process of hypertext/hypermedia authoring.

However, due to the lack of a cognitive model of the hypertext/hypermedia authoring process, it would be difficult to provide effective instructional strategies for learners when they are designing hypertext/hypermedia documents. The process of creating a hypertext/hypermedia product is complicated and challenging task for even the expert designer. If a cognitive model can be identified, it would be significantly helpful for instructional purposes for those who want to apply the idea of learning by hypermedia authoring to learners. The present study tries to provide a snapshot of cognitive processes in the authoring process. The cognitive model developed by this study will lead to a
better understanding of implementing learning by authoring hypertext/hypermedia through highlighting the underlying cognitive processes in which learners engage.

In addition, this study provides practical design guidelines for those who want to design/develop an authoring tool by identifying what cognitive process is occurring in the authoring process. This helps a developer of an authoring tool understand how the authoring tool should be designed for better use. Although there has been a great deal of improvement in the technique for developing an easy-to-use authoring tool, it remains questionable what functions are cooperating with the users’ cognitive processes. Some new technical functions and/or options have emerged along with new technology in today’s authoring tools. However, a more powerful authoring tool tends to be more complicated and require more intensive time investigation for a user to learn how to use it. In this trend, users tend to prefer an authoring tool not requiring a high-cognitive load to learn and use (Locatis & Ai-Nuaim, 1999). For this reason, identifying a cognitive model in hypermedia authoring helps a designer improve the usability and productivity of an authoring tool.

Finally but importantly, to improve an authoring tool’s functionality, this study provides a better understanding of how the adult learners’ cognitive processes are occurring in hypermedia authoring. It is accomplished by selecting graduate students as the research sample for this study. Most of the previous studies in learning by authoring have focused on young learners at K-12 levels (Bolter, 1991; J. Erickson & Lehrer, 1998, 2000; Harel & Papert, 1991; Lehrer et al., 1994; Liu, 1998; Liu & Rutledge, 1997; Reed & Rosenbluth, 1995; Spoehr, 1993; Spoehr & Shapiro, 1991). The research focuses were aimed at identifying how learning by hypermedia authoring improves the young learners. Their studies have provided meaningful implications of applying learning by hypermedia authoring as an instructional method by showing the young learners’ motivational improvement, better achievement, and deeper understanding. However, by selecting young learners, the studies did not show a clear picture of how the cognitively matured learners are learning through hypermedia authoring. This study is able to provide more feasible implications of how to design an authoring tool for use by adult learners.
CHAPTER 2
REVIEW OF LITERATURE

Introduction

The essential assumption underlying this study is that technology can be used as a cognitive tool for empowering learners’ cognitive skills and facilitating their understanding. Based on this assumption the theoretical framework of this study consists of five sections. The first section serves to ground the essential assumption of this study, the usefulness of computers as cognitive tools. Also, this section reviews from where the idea of learning by authoring hypertext document comes with respect to using computers as cognitive tools.

The second section then clarifies the theoretical background of learning by authoring hypertext. This section starts by defining hypertext, and it reviews two theoretical foundations of learning by authoring hypertext. The theoretical foundations are 1) the cognitive flexibility theory and 2) the tool mediation perspective.

The third section reviews the previous studies in learning by authoring hypertext. The purpose of this section is to provide an overview of what issues have been studied and how research has been developed thus far.

The fourth and fifth sections discuss how the knowledge transformation process can be modeled and what should be considered in building a cognitive model. Specifically, the fourth section investigates existing models of related areas of this study. Since very little attention has been paid to modeling knowledge transformation in
authoring hypertext, it is necessary to review what cognitive models have been developed in the related areas of writing process and teachers’ knowledge transformation. Finally, in the fifth section, some issues of modeling cognitive processes are discussed.

Computers as a Cognitive Tool

During the past three decades, technologies for educational purpose have been used to attempt to achieve better learning outcomes. Thirty years of educational research indicates that various uses of technology as are effective in education. Numerous studies have been conducted to examine interactive learning technologies in a variety of forms ranging from the earliest days of mainframe-based computer-assisted instruction to contemporary multimedia learning environments with accessibility via the World Wide Web (Reeves, 1999).

There are two major approaches to using computers for educational purposes; that is, people can learn “from” or “with” technologies. When computer technologies are used to deliver preprogrammed instructional lessons, it is referred to learning “from” interactive technologies (Jonassen & Carr, 2000). In the paradigm of learning from technologies, learners merely receive knowledge through use of the technologies as a vehicle. They are primarily considered as forms of “media” that are conveyors of information. Therefore, learners are implicitly regarded as the recipients of knowledge encoded in various forms of instructional media (Jonassen & Reeves, 1996). In this approach, learners’ interaction with the technologies is limited to inputting response and getting feedback from the technologies.

Learning “with” interactive technologies, on the other hand, considers interactive technologies as having an intellectual partnership between the learners and the technologies. (Jonassen & Carr, 2000). In other words, instead of using technologies to lead learners through prescribed interactions, learners may use technologies that function
as “the mindful engagement of learners”. When students learn with computer technologies, instead of being controlled by them, the technologies enhance the students’ thinking (Jonassen & Carr, 2000). Thus, technology can function as an intellectual “partner” that shares the cognitive burden with the learner of carrying out tasks (Salomon, Perkins, & Globerson, 1991). Research and evaluation of such tools shows that the learning students experience, the kinds of activities they engage in, and the effects of these activities are diverse and profound (Salomon & Almog, 1998).

The use of computers as cognitive tools indicates various ways of applying technology for learning. Examples of these applications include a collaborative tool with peers (Littleton & Hakkinen, 1999; Suthers, 1998), knowledge construction (Bruckman & Resnick, 1991; Harel & Papert, 1991), a tool for providing an adaptive instruction (Brusilovsky, Schwarz, & Weber, 1997), intelligent help (Baylor, 2002; T. Erickson, 1997), and semantic organization (J. Erickson & Lehrer, 1998; Lehrer, 1993; Lehrer et al., 1994; Salomon & Almog, 1998). By using these tools, learners can manipulate and interpret their ways of thinking. In this process, learners themselves function as designers, using software programs as tools for analyzing the world, accessing and interpreting information, organizing their personal knowledge, and presenting what they know to others. The studies of learning with interactive technologies suggest it may have more potential to enhance learning than the traditional way of learning from technologies (Jonassen & Reeves, 1996). Furthermore, learners develop critical thinking skills as authors, designers, and constructors of knowledge. Indeed, they learn more through learning with interactive technologies than from just receiving knowledge from the technology.

In general, the focus on critical thinking with interactive learning technologies is supported by the overall theoretical background of constructivism. Constructivism assumes that knowledge is constructed by learners as they attempt to make sense of their experience (Driscoll, 2000). Constructivism is concerned with the process of how learners construct meaning and knowledge in the world as well as with the results of the constructive process. Interactive learning technology can then facilitate learners in
constructing their own knowledge representations. The role of technology is thus to integrate tasks, goals, culture, resources, and human collaboration so that it enables learners to engage in active, mindful, and purposeful interpretation and reflection (Jonassen & Reeves, 1996).

Along with the idea of constructivism, there is another research tenet that suggests “learning is a process of becoming physically engaged with materials—to manipulate objects and build physical artifacts of understanding (Nicaise & Crane, 1999, p. 30)”.

From this perspective, the process of building or constructing artifacts involves students engaged in learning and understanding. Creating meaningful artifacts is thus an active process of learning. Contemporary researchers are attempting to apply this idea to technology used as cognitive tools by encouraging learners to produce digitalized artifacts in the forms of multimedia, hypertext, hypermedia, or programming. In this approach learners are authors or designers of the computerized product. The researchers in this approach believe that students more effectively learn through authoring a computerized product. There are various areas of investigation to apply this idea, and one of the areas to investigate is learning by authoring hypertext. The goal of learning by authoring hypertext is to encourage learners to restructure their own knowledge as a new meaningful knowledge structure. Through the authoring of hypertext documents, students gain more meaningful learning and deeper understanding of the subject matter.

### Theoretical Background

#### Defining hypertext

Hypertext, in general, can be defined as a form of electronic document in which data is stored as a network of nodes connected by links. Learners can browse nodes through links where the nodes can contain text, source code, graphics, audio, video, or
other forms of data (Smith, Weiss, & Ferguson, 1987). The key feature of hypertext is the nonlinearity of organizing and displaying text so that learners are able to access information from text in ways that are more meaningful for the learners (Jonassen & Reeves, 1996). It is based on the assumption that the learners’ paths of accessing information are more meaningful than the predetermined sequences of information. In traditional forms of instruction, learners most often are presented with information in a prescribed linear way. However, hypertext allows the learner to determine the order of accessing the information depending on his/her thinking patterns (Nelson & Palumbo, 1992).

The pervasive characteristics of hypertext are nodes and links. The node is the basic component of hypertext containing chunks of information in a variety of media forms. The organization of hypertext knowledge can be displayed as links. They describe how each node is associated with the other nodes. Learners can access any information by clicking a node, and then, they can move to another node through the links. Therefore, the links in hypertext transport the learner through the information space enabling him or her to move through the knowledge base. The node and link structures form a network of ideas for learners. A major characteristic of hypertext is that it enables learners to link information together in multiple ways and to make these relationships explicit (Nelson & Palumbo, 1992). A tool that authors a hypertext document sustains the nature of hypertext as described above. Thus, learners as authors of a hypertext document should identify what nodes are required, then link the nodes to make relationships between them, and finally structure the nodes as a body of knowledge to solve a given problem.

**Underlying theories**

There are many theories on which the idea of learning by authoring hypertext may be grounded. For instance, learning by doing can provide a philosophical foundation in terms of how learning can be more meaningful and facilitated. Constructionism may provide epistemological issues of how knowledge can be constructed for learners by
creating artifacts. Project-based learning or problem-based learning can be another theoretical foundation in terms of creating authentic products as the end result of learning by authoring hypertext documents. In the variety of the theoretical foundations, the cognitive flexibility theory and the tool mediation perspective are selected as the theoretical background of this study with respect to specifying knowledge transformation in the process of authoring hypertext product.

Cognitive flexibility theory. The cognitive flexibility theory focuses on how to improve learning capability by having learners restructure their knowledge with multidimensional representations at various situational demands. During the restructuring process, learners have to modify their knowledge to meet the situations. According to Jacobson (1994), “a central assertion of the theory is that advanced learning involves the development of flexible representations of knowledge that will help promote deep conceptual understanding and the ability to adaptively use knowledge in new situations” (p. 146). Instead of following predetermined instructional sequences and examples for how to solve a problem, learners have to bring together knowledge from various sources to the particular understanding or problem solving.

The restructuring process in cognitive flexibility theory is parallel to the knowledge transformation process in authoring a hypertext document. The process of knowledge transformation requires refining and relocating prior knowledge to modify it in solving a problem. Learners need to interconnect knowledge in multiple ways to find appropriate knowledge to solve a problem. The interconnectedness of knowledge provides a deeper and richer understanding. From the perspective of cognitive flexibility theory it is crucial to provide “the conceptual interrelatedness of ideas and their interconnectedness by providing multiple interpretations of content” (Jonassen, 1999, p. 225). This perspective is apparently an instructional approach in how to provide learning content specifically for the complex learning domain. From the knowledge transformation perspective, however, the authoring process itself encourages learners to construct the conceptual interrelatedness of ideas rather than providing multiple interpretations of content from the instructional side. Although the knowledge
transformation of authoring hypertext emphasizes the role of the learners’ authoring process rather than the use of it as instructional support, the idea of cognitive flexibility theory is equivalent to the knowledge transformation of learning by authoring hypertext.

Cognitive flexibility theory addresses complex knowledge domains where the knowledge base is vast and multiple solutions are possible to solve a problem (Grabinger, 1996). To enhance cognitive flexibility in a complex knowledge domain, it is important to avoid oversimplification of concepts and provide related cases with a variety of perspectives on the problem being solved. The variety of viewpoints then enables learners to think in multiple perspectives, which are required for reasoning about complex problems (Jonassen, 1999, 2000; Jonassen & Carr, 2000).

The idea of cognitive flexibility theory is well suited to the use of hypertext and hypermedia because of its multidimensional and nonlinear characteristics. The multidimensionality acts to provide various examples and cases representing a problem in a complex domain. Nonlinearity of hypertext and hypermedia systems means that learners can navigate Web-like interconnected concepts and knowledge. Consequently, the nonlinearity allows learners to adapt and apply multiple perspectives to solve a problem. Based on the multidimensional and nonlinear characteristics of hypertext and hypermedia, cognitive flexibility theory proposes the following design principles to enhance learning in a complex knowledge domain: 1) the use of multiple knowledge representations, 2) the linking of abstract concepts in cases to depict knowledge-in-use, 3) the demonstration of the conceptual interconnectedness or Web-like nature of complex knowledge, 4) emphasizing knowledge assembly rather than reproductive memory, 5) introducing both conceptual complexity and domain complexity early, and 6) the promotion of active student learning (Jacobson, 1994; Jacobson, Maouri, Mishra, & Kolar, 1995; Jacobson & Spiro, 1995; Spiro et al., 1992). Through the design principles of cognitive flexibility theory, hypertext and hypermedia systems can enhance the ability of the learner to learn, understand, retain, and adapt knowledge in ill-structured domains.

**Tool mediation.** The tool mediation perspective originally emphasizes the sociocultural context in which tools are developed and used. The tool as defined by
Vygotsky can range from culture and language to an artifact to use. Within the tool mediation perspective adopted in this study, it is assumed that authoring tools provide new ways of thinking to learn (Belisle, Zeiliger, & Cerratto, 1997). The notion of tool mediation is important to this study because it is assumed that a learner externalizes his or her cognitive process through an authoring tool, which mediates his or her thinking process as well. Vygotsky originally introduced the idea that a human being’s interactions with his or her environment are not direct but are instead mediated through the use of tools and environment (Hasan & Gould, 2000). Vygotsky’s theory emphasizes the importance of social interaction in individual development, which cannot be understood without references to the social milieu (Driscoll, 2000). More specifically, the idea of tool mediation is rooted in activity theory or the mediation of human activities by the use of tools (Hasan & Gould, 2000).

Activity theorists believe that “conscious learning and activity are completely interactive and interdependent (Jonassen, 2000, p. 105)”. Traditionally, behavioral and cognitive psychologists have regarded human performance as separate from the cultural environment. Thus, they examined human performance as the primary unit of analysis, ignoring the impact of mediating tools and signs. However, activity theory, in contrast, emphasizes sociocultural analysis that focuses on the activity system as the unit of analysis (Jonassen, 2000). From the activity theory perspective, human behavior cannot be understood independently of the sociocultural context. Furthermore, humans actively interact with the context and change it. The tools mediating activity are simultaneously the products of activity (Uden & Willis, 2001).

All human activity is involved in the use of artifacts as mediating tools such as instruments, signs, machines, and forms of work organization. From the tool mediation perspective, human cognitive processes are interdependent, interacting with tools and also mediated by them. In this context, the process of mediation by tools is very reciprocal in affecting those who use the tools. Consequently, human cognition is shaped by the use of tools (Uden & Willis, 2001). Tools mediate or alter the nature of human activity and, when internalized, influence humans’ mental development (Jonassen, 2000).
Tools can be both conceptual tools, such as language and signs, and physical tools, such technological devices like a computer (Uden & Willis, 2001; Waycott, 2001).

The perspective of tool mediation has particular relevance to this study because its purpose is to examine how learners are transforming their knowledge structure by interacting with the computer as a cognitive tool. As defined earlier, knowledge transformation is associated with interaction with an authoring tool. Knowledge transformation also involves considering how the use of an authoring tool affects the mental activities of transforming existing knowledge. The use of a tool like an authoring tool, leads mediated mental activities, and it also fundamentally changes all cognitive operations just as the use of tools alters the range or direction of cognitive process.

Learning by Authoring Hypertext

Advantages of learning by authoring hypertext

Given the nature of the hypertext system as described in the previous section, in order to author a hypertext document, learners must define and constantly refine the nature of a given problem to transform their knowledge into hypertext. This process demands considerable cognitive efforts. As a hypertext author, learners have to interact with the authoring tool to assemble, organize, and revise ideas. This approach makes technology become much more than an information-giving tool (Nicaise & Crane, 1999). In an effort to author hypertext material, learners have to reflect on their own knowledge to transform their existing knowledge into a hypertext product. In other words, learners need to refer to their knowledge structure in order to produce the given task.

Beichner (1994) studied the cognitive and affective impact of a multimedia editing task with nine seventh- and eighth-graders for an entire school year. Their task was to create a zoo kiosk with multimedia materials such as electronic documents, video
clips, audio, and pictures. Data was collected through interview, observation, and examination of their multimedia product. During the study, participants showed high consideration for the audience who will use their zoo kiosk. Students were so concerned about what the zoo visitors wanted to see in their multimedia product that they paid special attention to provide accurate information. Also, it was found that students actively helped each other to recall more information and devise better navigation methods. During this process, both students and teachers were very enthusiastic about their project. Also, it was observed that students were highly motivated. Beichner (1994) reported several positive findings: 1) learners demonstrated great concern for accuracy in their display; 2) learners quickly assumed the major responsibility for content and editing decisions; 3) learners accessed wide ranges of learning materials to find the content they desired; and 4) their commitment to and enthusiasm for the project remained very high. Through the analysis of the data, Beichner (1994) concluded, “the results showed the importance of designing curricula that incorporate realistic, highly involving tasks” (p. 67).

Liu and Rutledge (1997) also investigated the motivational impact of applying learning by authoring multimedia to at-risk high school students. Liu and Rutledge were also attempting to answer how the learner-as-designer approach contributes to the students’ learning of design knowledge. They used two groups: one group participated in authoring multimedia and the other group, as a control group, received instructions in how to use computer applications. The researchers found significant effects of authoring multimedia on student motivation. Participants who authored multimedia showed significantly higher intrinsic goal-orientation, task value, and self-efficacy than those in the control group, though there were no differences in extrinsic goal orientation and control of learning belief. For the design skills, participants in the authoring multimedia group were asked to list the tasks they needed to do to create their multimedia product. After completing the design task, participants were asked to rank the list of design skills in terms of importance of the skills. The analysis revealed that five skills among nine design skills were significantly recognized as important skills for authoring multimedia.
The identified design skills are planning, presenting, collaboration, mental effort, and interest, and these skills were identified as requiring higher cognitive efforts to perform. Besides of the quantitative data analysis, classroom observation and interviews were conducted in the study. Time on-task in authoring multimedia in class as well as out of class was noticeably increased in the group that authored multimedia. Students’ confidence in themselves also was significantly increased. Findings of this study showed a positive impact on the at-risk high school students. In addition, Liu and Rutledge also found that learners were very concerned about their audience that would use the multimedia product. It is very helpful to give the students a more realistic learning situation and an intrinsic learning goal.

Along this line, Liu (1997) examined the impact of using an authoring tool on the problem-solving ability and computer anxiety of learners in a study with graduate students. For the issue of problem-solving ability, she specifically investigated two research questions. The first question was to identify if authoring experience will improve problem-solving skills. The second question was to test if a longer authoring experience has more impact on the problem-solving skills than a shorter one. For the first research question, Liu compared the difference between the pretest and the posttest of problem-solving skills. The result revealed that the experience of authoring multimedia had a significantly positive effect on improving problem-solving skills. For the second research question, Liu compared 6-week period group and a one-semester period group of participants in a multimedia authoring class. There was no difference between the groups though it was concluded that authoring experience was helpful in improving the participants’ problem-solving skills regardless of the length of the authoring experience. In addition to the results of problem-solving skills, Liu also examined how authoring experience affected the participants’ computer anxiety. The result indicated that participants could significantly decrease their computer anxiety after having authoring multimedia experience.

In another empirical investigation, Liu (1998) examined the impact of multimedia authoring on creative thinking with fourth-graders. Specifically, she tested the effect of
multimedia authoring with different groupings (collaborative vs. individual) and levels of ability (low, intermediate, and high levels of ability) by comparing the pretest and the posttest. For the creative thinking issue, five aspects of creative thinking were measured: 1) fluency [how many relevant responses a child gives], 2) originality [how original the responses are when compared to a normative group], 3) abstractness of titles [how well the child captures the essence of the information via title], 4) elaboration [how many details are added to the main idea], and 5) resistance to premature closure [how well a child can make the mental leap that makes original ideas possible]. The result of the study showed that there were significant increases between the pretest and posttest in fluency, elaboration, and resistance to premature disclosure of creative thinking regardless of grouping (collaborative vs. individual) and levels of ability (low, intermediate, and high). However, the overall effect on problem-solving skills was not statistically significant. Liu also compared the effect of authoring multimedia with collaborative and individual groups. The collaborative group increased its elaboration and resistance to premature closure scores from the pretest to the posttest, whereas the individual group scores remained the same. For the levels of ability groups, there were two significant increases between the pretest and the posttest for the abstractness of title and resistance to premature closure. Overall, this study showed that hypermedia authoring had significantly positive effects on increasing fluency, elaboration, and resistance to premature closure. The increased fluency and elaboration indicated that multimedia authoring enabled students to be more productive and elaborative in developing their ideas.

Oughton and Reed (1998) studied the effect of hypermedia development on knowledge acquisition, general problem solving skills, and general design skills with 15 high school students. In their study the learners were enrolled in a multimedia development class, and they participated in the study for 8 weeks. Concept maps, problem-set solution, and learner log were used to measure learning in this study, and participants were measured every 2 weeks. Concept maps were used to identify how the participants’ mental model was evolving. For the problem-set solution, participants were
asked to report how they solved problems in the development of hypermedia. Learner logs were used to record thinking skills that were required to complete the particular task of the previous two weeks. Then, their reports were analyzed in terms of the six categories of Bloom’s cognitive taxonomy: it was categorized into low (knowledge and comprehension), middle (application and analysis), and high (synthesis and evaluation) levels of thinking skills. In the analysis of knowledge acquisition, Oughton and Reed found that the high level of thinking skill evaluation was continuously increased during the experiment. In addition, the low level of cognitive thinking was decreased as the experiment progressed. This result supported that participants were able to think about the concepts used in their tasks in a more sophisticated manner. Also the results indicated that the participants’ problem solving skills were significantly increased over the 8-week period. Regarding the issue of design skills, participants were mainly focused on planning and transforming in their cognitive process to develop a multimedia product.

In another experimental study Reed and Rosenbluth (1995) examined how learning by authoring hypermedia can improve students’ knowledge acquisition. This study was conducted for 4 weeks with high school students. Participants of this study were asked to develop a hypertext product about American life during the four decades of the 1920s, 1930s, 1950s, and 1960s. The analysis was conducted by comparing the pretest and the posttest to identify how learning was improved. The result of this study revealed that the participants’ knowledge was significantly increased. Participants learned the historical meaning of various events that took place in the four decades they studied. Also Reed and Rosenbluth examined the knowledge structure of hypertext, and they found that there were dramatic increases in complexity of the knowledge structure between the pretest and the posttest. This result indicated that participants could develop more detailed relationships between historical events and the causes and consequences of them. The authors of this study found an interesting result. While they could find significantly increased complexity of participants’ knowledge structure between the pretest and the posttest, there was no significant increased complexity of knowledge of the 1960s. Even in the pretest, the knowledge structure of the 1960s was evaluated to
have considerable detail record. It was concluded that participants already had a complex knowledge structure about the 1960s because it was relatively recent to participants. Thus, they had rich knowledge about the time period. From this result, the authors of this study suggested, “experience with specific knowledge or its degree of familiarity or unfamiliarity probably needs to be considered when getting students to learn and use an authoring language to develop knowledge structure” (p. 612). Along with this idea, the authors concluded that if learners did not have enough knowledge before learning by authoring hypertext, then the task paralleled the process of knowledge accretion and assimilation. But the authoring of hypertext documents can serve as a fine-tuning process of knowledge if learners already have detailed knowledge. This study provides an explanation of the role of prior knowledge in authoring hypertext products and its consequences.

There are several studies of how learning by authoring hypertext or hypermedia affects learners’ conceptual development (J. Erickson & Lehrer, 1998, 2000; Lehrer et al., 1994). Erickson and Lehrer (1998) reported the result of two years of longitudinal study with middle school students. Throughout their study, students developed hypermedia documents to teach their peers about topics in social studies. The research focus of this study was to investigate how students were developing critical standards to judge appropriate research questions for the topics of their hypermedia product and evaluate the quality of it. Students demonstrated improvement in refining research questions and conducting deeper investigations. The focus of their hypermedia design also evolved from eye-catching presentation to clarity of communication. Furthermore, students’ integration skills were improved. Lehrer and his colleagues conducted another study to develop an instructional model to apply learning by authoring hypermedia (Lehrer et al., 1994). In this study middle school students participated for 10 weeks. Their task was to develop a hypermedia product about American history. Throughout the study, a high degree of learner engagement was observed. Also, it was found that students developed “a number of skills valuable in many areas such as finding and interpreting information,
articulating and communicating knowledge, and using computers as cognitive tools” (p. 248).

**Instructional models of the learning by authoring hypertext**

There are several studies which have attempted to build an instructional model for learning by authoring hypertext. The approach of building instructional models focuses on providing instructional guidelines to support learners’ hypertext authoring. Also, the instructional models in their approach suggest an appropriate sequence for promoting knowledge transformation. General studies in this approach have distinguished four main phases: planning, transforming, evaluating, and revising (J. Erickson & Lehrer, 1998, 2000; Lehrer et al., 1994). In several studies, the phases have been employed to provide instructional sequences for hypertext authoring so that learners can effectively produce their multimedia programs. The results of these studies have shown the design sequence stimulates better performance from learners (Liu & Rutledge, 1997). In general, this approach provides prescriptive strategies to improve learners’ performance. Lehrer (1993) and Lehrer, Erickson, and Connell (Lehrer et al., 1994) proposed an instructional framework of 1) planning, 2) transforming, 3) evaluating, and 4) revision. A brief description was listed in the table below. Also Lehrer and his colleagues delineated what skills were required for each phase shown in Table 2-1.

Similarly Oughton and Reed (1998) suggested another instructional model of 1) planning, 2) transforming, and 3) evaluation and revising. Also they specified cognitive skills required in each stage. In their study, the planning stage is for generating ideas, organizing ideas, deciding on the content, and setting goals for a project. Transforming means to modify ideas into knowledge, and it requires understanding of how to use the features of the language and understanding the process involved in performing certain tasks. Evaluation and revising involves experimenting and checking for mistakes.

As another instructional model, Liu and Rutledge (1997) postulated 1) planning, 2) design, 3) production, and 4) evaluation and revision. It seems that they separated...
transforming into design and production. In their framework, design can be referred to as conceptual organization prior to displaying the author’s structural knowledge. Then the production stage is for determining how to display the organized concepts in terms of using a given authoring tool.

Table 2-1. Hypertext Authoring Procedure, Design Component, and Primary Skills: Adapted from Lehrer et al., (1994)

<table>
<thead>
<tr>
<th>Phases</th>
<th>Design Component</th>
<th>Primary Skills Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Defining the Nature of the Problem</td>
<td>Question Posing</td>
</tr>
<tr>
<td></td>
<td>Problem Decomposition</td>
<td>Team Collaboration</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>Task &amp; Role Assignments, Developing Timelines</td>
</tr>
<tr>
<td>Transforming</td>
<td>Finding Information</td>
<td>Document Search Techniques, Using Keywords in Electronic Search</td>
</tr>
<tr>
<td></td>
<td>Developing New Information</td>
<td>Interviewing, Developing, Questionnaires, etc.</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Selecting Information</td>
<td>Note Taking, Summarization, Data Analysis</td>
</tr>
<tr>
<td></td>
<td>Organizing Information</td>
<td>Use of Database Tools, Semantic Mapping</td>
</tr>
<tr>
<td></td>
<td>Representing Information</td>
<td>Segmenting Video &amp; Sound, Interweaving Media, Graphic &amp; Video Production</td>
</tr>
<tr>
<td>Revising</td>
<td>Evaluating the Design</td>
<td>Articulating Intensions, Public Speaking, Use of Display Tools</td>
</tr>
<tr>
<td></td>
<td>Revising the Design</td>
<td>Taking Design as an Object for Thought, Soliciting Peer Feedback</td>
</tr>
</tbody>
</table>

In summary, the studies of modeling an instructional sequence have distinguished four main phases: planning, transforming, evaluating, and revising (J. Erickson & Lehrer, 1998, 2000; Lehrer et al., 1994). More specifically, planning means to decide the nature of the problem and develop ideas about the overall structure of the document. Transforming means the modification of information into knowledge. Evaluation relies on the designers’ abilities to solicit feedback, which in turn relies upon their skills in articulating their goals and intentions to others. Revision requires multiple cycles of drafting and revision in order to make a successful product. The four phases have been
employed to provide an instructional sequence for authoring hypertext so that learners can effectively develop their multimedia products. The results of these studies have shown that the design sequence stimulates better performance from learners (Liu & Rutledge, 1997).

Summary

Hypertext authoring provides more opportunities for learners to develop sophisticated knowledge structures because it requires that they use multiple and linked mental representations to author hypertext. Learners working with authoring environments outperformed the control group in terms of articulating and defending essay topics (Spoehr, 1993). Learners’ knowledge structures became more sophisticated and their design skills emulated a cognitive framework and a problem solving process. As a result, their problem-solving skills increased and became more complex (Oughton & Reed, 1998). Similar results were reported in that students engaged in hypertext authoring demonstrated increased cognitive processes such as finding, interpreting, and articulating information and knowledge (Lehrer et al., 1994). These cognitive processes seem to be a promising advantage of authoring hypertext.

The purpose of authoring a hypertext document is to facilitate learning by requiring learners to assemble information, make connections and conclusions, and demonstrate an understanding by creating a comprehensive and multimedia artifact (Nicaise & Crane, 1999). Regarding the instructional model of learning by authoring hypertext, planning plays a role as an initial step in locating required information; however, the identified information can be discarded depending on the author’s decision when a learner transforms or revises a hypertext document. Among planning, transformation, and revision, transformation and revision are more critical in producing an artifact as a final product in the hypertext authoring process. In this regard, transformation and revision are the main activities in which learners engaged while authoring hypertext. Therefore, the main benefits of implementing hypertext authoring
may come from transformation and revision. By performing transformation and revision, learners modify and adopt their knowledge structure as an artifact, hypertext. It has to be explained how cognitive strategies contribute to the knowledge transformation process. For instance, classification of information, one of the most identified cognitive strategies, could occur at any time during hypertext authoring. However, it is unclear how classification is related to the other cognitive strategies. Indeed, it has not been explained when learners use this cognitive strategy.

In fact, little is known specifically about the cognitive process of knowledge transformation to explain how cognitive strategies affect knowledge transformation, when learners use the cognitive strategies, and in what condition the strategies are used. Indeed the previous studies have loosely authenticated how learners use the authoring tool for their project. For instance, it has not been identified what functions would be effective for learners’ authoring. More specifically, there is a need to identify key components of developing ideal authoring tools. That is, if there are distinctive learning processes or patterns, they can be applied for developing an authoring tool.

**Existing Cognitive Models of Related Areas**

Due to the lack of the existing cognitive models of knowledge transformation in authoring hypertext document, it is helpful to review existing cognitive models of related areas to build a framework to model the cognitive process of knowledge transformation. Two research disciplines are selected as the relevant area to this study: 1) the writing process and 2) the teachers’ knowledge transformation. Both of these areas of research attempt to answer how we modify our prior knowledge or information to solve a given task.

First, the studies in writing process explain how a writer organizes his or her knowledge to compose a story. While composing a story, a writer has to identify a topic
of the story and arrange knowledge in a logical way to make the story consistent. Writing can be best understood as a set of thinking processes, which writers orchestrate or organize during the act of composing (Flower & Hayes, 1981). These features of the writing process are very similar to those of knowledge transformation in authoring hypertext product with respect to organize knowledge to make a meaningful product for a given task.

Second, the studies of teachers’ knowledge transformation are mainly focused on explaining how teachers modify their content knowledge to teach the different levels or situations of students. Teachers, not surprisingly, have to transform their domain knowledge in a variety of ways to make the knowledge meaningful for their students. During the transformation of domain knowledge, also referred as content knowledge, teachers have to make their knowledge comprehensible to others. The teacher is expected to be able to transform the subject content knowledge to pedagogical content knowledge for effective learning (Chen & Ennis, 1995). The transformation of the content knowledge is involved in various representational formats, such as analogies, illustrations, examples, learning cues, and so on. These various representational formats are very similar to the process of knowledge transformation in authoring hypertext in respect to refining and relocating knowledge in order to author for the purpose of a given goal.

Writing process

There are two important models to consider regarding the cognitive models of writing process by: 1) Flower and Hayes (1981) and 2) Scardamalia and Bereiter (1987). The cognitive model of writing proposed by Flower and Hayes is mainly focused on modeling a generic cognitive process of writing, while the model by Scardamalia and Bereiter is contrasting how mature and immature writers are composing differently.

In Flower and Hayes’ cognitive model of the writing process they argued that writing is a set of thinking processes rather than a series of linear steps or discrete stages (Flower & Hayes, 1980a, 1980b, 1981; Zimmerman, 1998). The process-oriented
approach to writing process represents that writing takes place as very recursive processes in generating and organizing units of ideas to compose. They differentiated their model from the traditional view of writing as a series of sharply distinct stages. Flower and Hayes criticized that traditional stage models of writing are inaccurate in describing cognitive process in writing. In fact, it is very hard to explain what cognitive activities are taking place in writing because writing is a constant process of re-vision or “re-seeing” that goes on while writers are composing (Flower & Hayes, 1981). Also, Flower and Hayes (1981) characterized that the processes of writing are hierarchically organized. In their perspective, the cognitive process in writing consists of some essential elements of mental activities, and each element has sub-processes, which are hierarchically structured. For instance, when a writer is in the planning phase, he or she may need to execute sub-goals to complete the planning. Consequently, the writer has to use sub-processes to meet the sub-goals. This perspective reflects one of the most common heuristic problem-solving strategies, means-end analysis with using sub-goal strategies, which identifies the gap between the goal and current status and applies sub-process to reduce the gap (Haberlandt, 1997; Zimmerman, 1998).

In this perspective, they proposed a model of the writing process with three major parts: 1) the task environment, 2) the writer’s long-term memory, and 3) the writing process as illustrated in Figure 2-1 (Flower & Hayes, 1981). In this model, the task environment represents the rhetorical problem influencing the writer, including the topic, audience, and situation prompting the writer to write, and eventually including the growing text itself. Writing as a rhetorical act requires a writer to define the rhetorical situation, including the topics and the audience. Moreover, the rhetorical problem includes the writer’s own goals in writing. As composing proceeds, the growing text itself is becoming a new element, which constrains the writing process.

The writer’s long-term memory is the knowledge resources in which the writer has stored knowledge, not only of the topic, but also of the audience and of various writing plans. The writer may retrieve relevant knowledge in order to compose. In retrieving the knowledge, it is important to find the cue that activates a network of useful
knowledge for the purpose of writing. After activating the useful knowledge in order to compose, the writer should reorganize and adapt that knowledge to fit the demands of the rhetoric problem. Together, the task environment and the writer’s long-term memory provide the context in which the writing process occurs.

The writing process consists of the processes of planning, translating, and reviewing under the control of a monitor. Planning means the formation of an internal
representation of the knowledge that is used in writing. It involves three sub-processes: generating, organizing, and goal setting. Generating is the act of generating ideas, which also includes retrieving relevant information from the writer’s long-term memory. The process of organizing is to form and develop new concepts to solve the rhetoric problem. Goal-setting guides the writer in what should be generated, developed, and revised.

Translating is another element of Flower and Hayes’ cognitive model. It plays a role in externalizing ideas into visible language. The process of translating requires the writer to juggle knowledge. Another part of the writing processes is reviewing. Reviewing consists of two sub-processes: evaluating and revising. Both of them are interacting recursively; that is, the result of evaluation triggers revising the growing text, and the revised text is evaluated again in the reviewing process. Monitoring is a process that involves controlling planning, translating, and reviewing. To monitor is to determine when the writing process should move from one process to the next through observing the current process and progress.

In sum, Flower and Hayes (1981) identified four key points through their model: (1) the writing process involves “a set of distinctive thinking processes” during the composition process; (2) these thinking processes have “a hierarchical, highly embedded organization”; (3) composing is “a goal-directed thinking process”; and (4) writers are developing “high-level goals and supporting sub-goals”, and these goals are dynamically interacting together (p. 366).

Scardamalia and Bereiter (1987) proposed two other cognitive models of writing: 1) knowledge telling and 2) knowledge transforming in written composition. Their approach in modeling the writing process is different from that of Flower and Hayes in two respects. First, the level of analysis to build a model is more specified than Flower and Hayes’ model. Unlike Flower and Hayes’ model, Scardamalia and Bereiter proposed more detailed cognitive processes in their models of writing. Specifically, their models of knowledge telling and knowledge transforming seem to focus more on how writers develop sub-goals of the writing and link them to make a consistent story. Second, Scardamalia and Bereiter’s model is a comparative approach by contrasting differences
between mature and immature writers corresponding to the models of knowledge-transforming and knowledge-telling respectively. Note that the terms “mature” and “immature” does not mean to compare expert and novice rather to represent the reference groups of their study. Rather, contrasting two models is to differentiate how knowledge is brought into the writing process and what happens to knowledge in that process.

Figure 2-2. Structure of the Knowledge-telling Model: Adapted from Scardamalia and Bereiter (1987)
The knowledge-telling model describes how writers generate text content without the need for an overall plan or goal for an elaboration of problem constraints, which are important factors in Flower and Hayes’ cognitive model (Scardamalia & Bereiter, 1987). The knowledge-telling process illustrated in Figure 2-2 works as below.

First, writers locate topic and genre identifiers to construct memory probes. The locating process of those identifiers is similar to searching cues to construct a storyline. Through the searching process, relevant information in memory becomes available for use in composition for writers. Once the information is available to use, writers can retrieve it to examine if the information is appropriate for the topic. If the retrieved information is identified as useful and appropriate for composing, the writers are then able to generate a unit of text. However, if the retrieved information does not fit into the context, writers continue to retrieve other information in their memory. In this process, once a unit of text has been produced, it serves as an additional source for topic and genre identification in locating available information for writing.

The knowledge-transforming model is not an elaboration of the knowledge-telling model but shows how additional cognitive processes are involved in a more complex problem-solving process. In fact, the knowledge-transforming model retains the knowledge-telling process as a sub-process within this model illustrated in Figure 2-3.

The feature of the knowledge-transforming model most distinct from the knowledge-telling model is that analytical processes are added. “Problem analysis and goal setting” intervenes prior to activating the knowledge-telling processes. In addition, the knowledge-transforming model emphasizes operational aspects of content and discourse knowledge. In the knowledge-transforming model, the content and discourse knowledge influence the content and rhetorical problem spaces respectively. Those two problem spaces represent that writers are operating knowledge states from content and
discourse to “alter the text, goals, or relations between them” (Scardamalia & Bereiter, 1987, p. 146).

Figure 2-3. Structure of the Knowledge-transforming Model: Adapted from Scardamalia and Bereiter (1987)
According to Scardamalia and Bereiter, the content problem space is concerned with operating the relationships of ideas to the thoughts, feelings, and motives of the text. However, the rhetorical problem space, in contrast, is concerned with achieving goals such as topic and/or theme of the text and potential reactions from the audience. Thus, the problem translations between the content and rhetorical problem spaces are to serve as a coordination process to find a most appropriate way to compose knowledge into a text.

The review of the cognitive models by Flower and Hayes and Scardamalia and Bereiter provides two important implications for the knowledge transformation process in authoring a hypertext document: 1) content knowledge and 2) rhetorical knowledge. The content knowledge serves as resources for the writing process. Although Flower and Hayes did not explicitly propose content knowledge in their model, some portion of the writer’s long-term memory is corresponding to the content knowledge as a resource of knowledge for the topic. Scardamalia and Bereiter exclusively emphasized the existence of content knowledge in their model. The content knowledge as a resource for transforming should be considered one of the key factors in knowledge transformation.

The role of rhetorical knowledge is to integrate contents to a certain structure with consideration of audience and purpose. Flower and Hayes seem to separate rhetorical problem and knowledge. In their model, the rhetorical problem is a sub-process of task environment; yet, the rhetorical knowledge such as “audience and writing plans” is described in the writer’s long-term memory. Scardamalia and Bereiter, in contrast, regarded the rhetorical knowledge as a separate factor in their model. However, the functions of rhetorical knowledge are similar in Flower and Hayes’ model as well as Scardamalia and Bereiter’s. Regardless of the location of rhetorical knowledge in the models, rhetorical knowledge shows that writers consider the topic, audience, and consistency of their composition. More importantly, writing process is a product of coordinating between content and rhetorical knowledge. Thus, the knowledge transformation is also analyzed as to how these types of knowledge are working together in transforming content knowledge into a hypertext document with consideration of rhetorical aspects.
Teachers’ knowledge transformation

The studies of teachers’ knowledge transformation are similar to that of modeling knowledge transformation in authoring hypertext with respect to transforming certain existing knowledge to meet a given purpose. For teachers, the existing knowledge corresponds to what they already know, and the transformed knowledge corresponds to what they modify to teach their student. When teachers teach certain domain knowledge, it usually is not taught in its original form as stored in the teacher’s memory (Chen & Ennis, 1995). Thus, teachers have to restructure their knowledge. Moreover, reviewing the studies of explaining teachers’ knowledge restructuring process give theoretical foundations for this study.

Shulman (1986) first conceptualized teacher content knowledge into three categories, and later elaborated it into seven categories (Shulman, 1987). The three categories are 1) content knowledge, 2) pedagogical content knowledge, and 3) curricular knowledge. The categories of elaborated version are 1) content knowledge, 2) general pedagogical knowledge, 3) curriculum knowledge, 4) pedagogical content knowledge, 5) knowledge of learners and their characteristics, 6) knowledge of educational contexts, and 7) knowledge of educational ends, purposes, and values. Although the seven categories are elaborated from the earlier version, some of the categories seem to merely stem from the pedagogical content knowledge of the earlier version of teacher content knowledge. For instance, three categories of knowledge of learners, educational contexts, and ends can be included in the pedagogical content knowledge in terms of supporting pedagogical knowledge. Thus, three categories of teacher content knowledge are reviewed as key elements of teacher content knowledge: 1) content knowledge, 2) pedagogical content knowledge, and 3) curricular knowledge.

According to Shulman (1986), content knowledge refers to “the amount and organization of knowledge per se in the mind of the teacher (p. 9)”.

It represents understanding of the structures of the field or discipline in which teachers are specialized
Pedagogical content knowledge is the unique form of professional understanding held by teachers (McMeniman et al., 2000). Specifically, it is about how teachers make the content knowledge understandable to students. Thus, the pedagogical content knowledge goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching (Shulman, 1986). Curricular knowledge is represented by the full range of programs designed for the teaching of particular subjects and topics at a given level. Specifically, it is the teachers’ understanding of the materials and the scopes and sequences of the programs, tests, testing materials (McMeniman et al., 2000; Shulman, 1986).

Among the three types of teacher knowledge, pedagogical content knowledge plays a key role in transforming and modifying teachers’ content knowledge into teachable content. As Shulman (1986) explained, teaching necessarily requires a teacher’s understanding of what is to be learned and how it is to be taught. Pedagogical content knowledge is “how it is to be taught”. This knowledge consists of understandable forms of representations for the content knowledge such as analogies, illustrations, examples, explanations, demonstrations, learning cues, and drills (Chen & Ennis, 1995). Along with the categorization of teacher content knowledge, Shulman (1987) proposed a model of pedagogical reasoning and action to explain how teachers are delivering content knowledge and increasing their knowledge. This model consists of a cycle through the activities of comprehension, transformation, instruction, evaluation, reflection, and new comprehensions. Shulman specified four sub-processes of transformation in this model as preparation, representation, selection, and adaptation and tailoring. Specific descriptions are listed in Table 2-2. The sub-processes represent how teachers are acting to transform content knowledge. Similar to this model, another study proposed a three-stage model: 1) interpretation, 2) representation, and 3) adaptation. Through the stages, teachers clarify content knowledge to interpret, determine a useful representation of the knowledge to transform, and adapt the transformed knowledge to meet the students’ characteristics (Wilson, Shulman, & E., 1987).
In addition to those two models, Chen and Ennis (1995) conducted a study through observation, interview, evaluation, and concept mapping to provide in-depth information about the characteristics of the teachers’ knowledge transformation. They identified “understanding of teachability” and “personalization of curricula and content.”

First, teachability refers to teachers’ decision to include and exclude particular concepts and skills to teach. Teachers exclude some concepts and skills not because they were unimportant, but because they are difficult to teach. In other words, when teachers need to decide content knowledge to teach, they decided what knowledge should be taught with the teachers’ perceptions of the importance of the content and of the student learning condition. The perception of the student learning condition reflects the teachers’ decision whether students are capable to learn the content. This perception is to figure out whether the content they are delivering is beyond learners’ capability or not. In this context, the understanding of teachability proves a considerable implication to model knowledge transformation in authoring hypertext with respect to how authors of hypertext decide what knowledge is included or excluded.

Second, the personalization of curricula and content knowledge refers to teachers’ personalized perspective in transforming content knowledge. Chen and Ennis (1995) found that in the teachers of their study, differentiation in instructional delivery of content was evident though teachers were teaching the same topic and shared a similar understanding of teachability. The personalized feature of curricula and content knowledge is “mediated by personalized pedagogical content knowledge repertoire and personalized understanding of educational goals” (p. 400). Teachers had a substantial pedagogical content knowledge repertoire of using various types of representation. Also, their perceived educational goals were different. Chen and Ennis concluded that personalization is a salient factor that influences content knowledge transformation. Even if teachers have a similar subject content knowledge and teach the same topics, they use different representations that are perceived personally in terms of their curricular goals. This conclusion suggests that authors of hypertext may organize content differently in
terms of their perceived goal of authoring, even if they have relatively similar knowledge structure.

The review of teachers’ knowledge transformation processes provides three implications for the knowledge transformation model of authoring hypertext: 1) criteria to transform knowledge, 2) personalizing content, and 3) existence of instructional knowledge. The models of teachers’ knowledge transformation propose that teachers consider teachability in transforming their content pedagogical knowledge. The issue of teachability is concerned with the learners’ ability and the level of difficulty of the content knowledge. By considering teachability, teachers can make the learning content more meaningful and comprehensive to learners. Teachability is a very important feature in evaluating the quality of a hypertext document that learners produce.

Table 2-2. Sub-processes of Transformation in Pedagogical Reasoning and Action: Adapted from Shulman (1987)

<table>
<thead>
<tr>
<th>Transformation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>Critical interpretation and analysis of texts, structuring and segmenting, development of a curricular repertoire, and clarification of purposes</td>
</tr>
<tr>
<td>Representation</td>
<td>Use of a representational repertoire which includes analogies, metaphors, examples, demonstrations, explanations, and so forth</td>
</tr>
<tr>
<td>Selection</td>
<td>Choice from among an instructional repertoire which includes modes of teaching, organizing, managing, and arranging</td>
</tr>
<tr>
<td>Adaptation and Tailoring to Student Characteristics</td>
<td>Consideration of conceptions, preconceptions, misconceptions, and difficulties, language, culture, and motivations, social class, gender, age, ability, aptitude, interests, self concepts, and attention</td>
</tr>
</tbody>
</table>

The personalizing content means that teachers transform their content knowledge in a personalized form for each individual learner to meet his or her learning goal. It is similar to rhetorical knowledge in terms of considering the audience. In learning by
authoring hypertext it is assumed that the hypertext product is used for a real audience such as peers. Thus, the awareness of the end-user of a hypertext document is a very important factor to consider during the authoring process.

Lastly but more importantly, the models of teachers’ knowledge transformation show that teachers seriously consider how their knowledge should be transformed to ensure an effective instruction. Further, the studies of teachers’ knowledge transformation commonly suggest that teachers try to apply their instructional knowledge in an act of transforming the content knowledge. The notion of instructional knowledge is a different aspect from the majority of studies on learning by authoring hypertext.

Summary

The review of existing cognitive models in related areas provides a variety of implications for this study. The cognitive models in writing process reveal that there are two distinctive types of knowledge: 1) content knowledge and 2) rhetorical knowledge. Also, it is revealed that their functions are exclusively different. The two different types of knowledge play a role of providing informational resources in the process of knowledge transformation as an architectural element of writing processes. On the other hand, while the cognitive models in writing process show the architectural aspects, the cognitive models in teachers’ knowledge transformation provide operational features of knowledge transformation. The implications of criteria for transforming knowledge, personalizing content, and the existence of instructional knowledge reveal what cognitive processes possibly take place between the content knowledge and rhetorical knowledge as identified from the cognitive models in writing process.

Although the potential cognitive elements and processes are identified from the existing cognitive models of related areas, another question then follows of how they can be integrated into a model of knowledge transformation. Integration of the cognitive elements and processes as a model should sustain the consistency and reliable predictability of the knowledge transformation process by the model. Ensuring the
consistent and predictable rules of the model can be accomplished by validated data collection methods to model the cognitive process of knowledge transformation. In addition, in order to make predictable rules within the model there must be a reliable interpretation of given data sources from the validated data collection methods. All of these issues are related to how to model cognitive process. Modeling of cognitive process is not merely assembling collected data; rather, it is how a researcher collects data and interprets them. The next section discusses the fundamental issues of modeling cognitive process. Understanding these issues provides instruction in how to build a cognitive model from the results of this study and yield a more reliable cognitive model of knowledge transformation in authoring hypertext.

**Issues of Modeling Cognitive Process**

One of the benefits of modeling cognitive processes is that it makes easier to understand how a human operates tasks or solves problems by providing explicit representational formats of knowledge in the model. Indeed the practical value of building a cognitive model is that it enables researchers to have a more reliable and predictive interpretation for human cognition being studied. For instance, a sophisticatedly modeled cognitive process of complex tasks will help people find effective ways to train a novice. Similarly, if there is a well-established cognitive process model of operating dangerous tasks, the cognitive model will be useful for someone to decrease dangerous errors by learning from it. However, regardless of the benefits of having a cognitive model, modeling cognitive process challenges researchers because of the invisible nature of human cognition.

Because human cognition takes place inside brain, researchers make observations to investigate cognitive processes. Then, they interpret the observations to explicitly reveal the cognitive process. As a result, a series of cognitive processes can be modeled
based on the interpretation. During the modeling process, the higher the correspondence between data sources and interpretation, the better is the cognitive model. If there is mismatching or low fidelity between data sources and the interpretation, a cognitive model from the interpretation fails to represent the cognitive process and be a flawed representation. Thus, the importance of a framework of collecting and interpreting data cannot be overemphasized in the studies of modeling cognitive process.

It is also necessary to justify in the modeling process how the data were collected and interpreted. The justification process can be accomplished by articulating epistemological assumptions grounding the model while addressing questions, as claimed by Pemberton (1993): “What are my methodological assumptions? What factors are likely to be included or excluded by mode of inquiry? What assumptions shape the way I make my observations and interpret data?” (p. 55). Answering these questions makes a cognitive model be more predictive and reliable. Therefore, for the same justification process it is necessary to articulate what are the purposes of this study and what cognitive processes are being investigated. A review of the issues of modeling cognitive process articulates how to interpret the results of this study.

The purpose of this study is described by the research questions: 1) “What cognitive processes are involved in knowledge transformation through hypertext authoring?” and 2) “How are these cognitive process interrelated?” Presumably, this study is attempting to build a cognitive model of knowledge transformation in authoring hypertext. Modeling knowledge transformation in authoring hypertext reveals how learners are transforming their prior knowledge into hypertext, digitalized artifacts, with the assumption that the model represents certain commonalities of authoring process among learners. Consequently, the cognitive model would provide effective ways to teach knowledge transformation. Having a model as a framework to understand the cognitive process associated with authoring hypertext would make possible the development of a general and comprehensive description of the entire complex cognitive process of knowledge transformation in authoring hypertext. However, comparatively
little attention has been paid to the issue of modeling how learners are authoring hypertext.

Although it is apparent what benefits we can take from having a cognitive model of knowledge transformation in authoring hypertext, it is necessary to clarify a fundamental question before attempting to build a cognitive model. What is a cognitive model? More specifically, how is the shape and degree of specifications of the cognitive model determined. Further, the answer to these questions may lead more questions, such as, “What constitutes a cognitive model?”, “How many dimensions should be considered in building a model?”, “To what extent should a model be domain-specific or independent?”, and so forth.

Defining a cognitive model

Before defining what a cognitive model is, it is necessary to define what a model is. This study takes a definition of a model as a conceptual framework proposed by Pemberton (1993);

“Models are conceptual frameworks which allow us to interpret, structure, and comprehend our environment. They assist us in making sense of the flood of sensory data we receive every waking moment from the world around us, and they help us to systematize that world by revealing its underlying patterns and regularities” (p. 42).

According to this definition, a model should be able to provide a means of interpreting or understanding how a system, as a set of interwoven concepts, is interacting with its environment. Furthermore, the interaction should deliver a meaningful relationship within the system. Although the definition of a model provides a brief definition of what a model is, it is still too general for the context of this study to model a cognitive process. Indeed, this study is bound to the context of cognitive process. Thus, it
is important for this study to clarify the conceptual scope of defining what a cognitive model is. By establishing the conceptual scope of a cognitive model, it empowers the clarity of the cognitive model of knowledge transformation in authoring hypertext, which is proposed by this study. In addition, this study’s proposed model must be thoroughly informed with the knowledge of exactly what a model is, how it can be used effectively, and what its limitations are, as Pemberton (1993) insisted. Defining a cognitive model was a first step to answer the questions above. Since this study focused on building a cognitive model, it was decided to take perspectives from studies that attempted to build a cognitive model in a similar research area as this study. According to Erickson and Lehrer (2000), the hypertext authoring process is similar to that of writing in terms of organizing, associating, and generating ideas. Also multimedia authoring skills and multimedia critical analysis correspond closely to traditional skills of text writing and critical reading (Lemke, 1998). In addition to the similarity between writing process and authoring hypertext, various cognitive models of composition or writing have already been developed so that it would be appropriate for reviewing how cognitive models have been discussed to define what a cognitive model is for the purpose of this study.

Flower and Hayes, one of the mostly influential contributors in proposing a cognitive model of writing process, defined a model as a metaphor for a process: a way to describe something in their study proposing the structure of the writing model (1980b; 1981). Their notion of a model emphasized the descriptions of a process because they assumed that writing is a part of dynamic thinking process. Thus, they needed to take a knowledge representation perspective in respect to cognitive psychology to illustrate how the thinking process is taking place. While Flower and Hayes’ cognitive model of writing process has been widely cited (Zimmerman, 1998), there were several critiques pointing out some mis-justifications of their cognitive model of writing (Cooper & Holzman, 1983, 1985; Petrosky, 1983). As responses to the critiques, Flower and Hayes made counterstatements to the argumentations of Cooper and Holzman and Petrosky in separate papers (Flower, 1984; Flower & Hayes, 1985). This study does not have as its purpose evaluating whose model is more applicable for the writing process. Yet
reviewing what was argued and how counterstatements were made inductively provides information that should be considered in building a cognitive model.

**Grounding primary assumption to cognitive process**

It is important to identify what a primary assumption of the phenomenon of interest is. Cooper and Holzman (1983) raised two issues to Flower and Hayes’ cognitive model of writing process: 1) the labeling issue of the components in the Flower and Hayes’ cognitive model and 2) the validity of using protocol analysis to reveal writing process. For the first issue, Cooper and Holzman argued that Flower and Hayes’ model could be more neatly fit into different categories that borrowed from another perspective. For the second issue, they insisted that verbal reporting might not be appropriate to reveal the cognitive process of writing; thus, Flower and Hayes’ cognitive model was based on falsely collected data according to Cooper and Holzman’s argument. Although Cooper and Holzman raised two different questions for Flower and Hayes’ cognitive model, their critiques seem to converge into one main question of how well a model represents a writing process. In essence, Cooper and Holzman believed that direct evidence of cognitive process in writing is simply unavailable. Indeed, they argued that even if data to build a cognitive model in writing is collectable and observable, if a proposed cognitive model is too underspecified to be testable then the cognitive model cannot be acceptable. The reason why Cooper and Holzman emphasized testability of a cognitive model is to ensure that testability is the basis on which theorists claim validity for models. Further, in respect to testing a model, they believed that a model of writing could be tested when writing is evaluated as a product rather than a process. Their point was that a model in social science should be more than literal descriptions of reality, but, rather, is an abstract rule with clear definition (Cooper & Holzman, 1983). Contrastingly, Flower and Hayes insisted that their model was to describe the process of writing. Their point was that the best way to model the writing process is to study a writer in action. In this context, they
were attempting to capture accurate reality of cognitive process in actions (Flower, 1984; Flower & Hayes, 1980b, 1981).

Their responses and counterstatements contrasted different perspectives of defining what a cognitive model should be. Cooper and Holzman’s argumentation focused on testability of the model, and their doubts to Flower and Hayes were on how well the writing process can be distinctive as described in Flower and Hayes’ model. Further, Cooper and Holzman believed that the model should be able to provide a set of rules to explain the writing. In contrast, Flower and Hayes argued that a model should represent the reality of the writing process. It seems that the debates between two different perspectives from Cooper and Holzman and Flower and Hayes can be converged into the issue of primary assumption of the phenomenon to model. Flower and Hayes assumed writing as a process of thinking of writing. Cooper and Holzman assumed that the writing should be modeled with testability for the validation issue. For them, more importantly, a model of writing should be modeled as a product rather than a process because the process of writing cannot be distinctive.

Their debates reveal that one important criterion to build a cognitive model is the clarification of what primary assumption is assumed about the phenomenon being studied. By determining a primary assumption about the phenomenon, it then provides appropriate angles to interpret the phenomenon and build a model to explain it. Based on the primary assumption, a researcher can clarify model specification that is describing how the factors of the cognitive model are working together. The debates between Flower and Hayes and Cooper and Holzman came from the different perspectives of writing as a process or product. For Flower and Hayes writing is a process of generating and organizing ideas to compose. However, for Cooper and Holzman, writing is a product that consists of a set of “stages” in the completion of the writing (Cooper & Holzman, 1983). The different assumption of what writing is makes different interpretations. In summary, it is apparently important to identify and clarify what a primary assumption is for those who want to build a cognitive model.
Validating data collection method

It is also important to apply an appropriate method to collect data, and there is the question of whether the data collection method is valid for the purpose of a given cognitive model. In other words, a researcher should be able to answer the question of how well a method used to collect data represents a cognitive model grounded on the collected data. Regarding this issue, there is another critique by Petrosky (1983) in reviewing Flower’s book entitled *Problem-solving Strategies for Writing* (1981). Although the book was only describing her and Hayes’ cognitive model of writing, it is still valuable to identify what a cognitive model should be by reviewing Petrosky’s critique and the response by Flower because the debate originally focused on the nature of Flower and Hayes’ cognitive model of writing process. In the review, Petrosky pointed out that Flower ignored reflective, associative, metaphoric, intuitive, and imaginative thinking because they were not easily represented as aspects of conscious, goal-directed problem-solving. In essence he pointed out that Flower was oversimplifying the writing process as a mechanical outcome of problem-solving (Petrosky, 1983). His rationale underlying the critique seems that there are many aspects of writing process, which cannot unfold through a conscious thinking process. His critique is also closely related to the data collection method, verbal reporting, as Flower used. The verbal report was used to capture a detailed record of what was going in the writer’s mind during the act of composing. In fact, verbalizing the writing process is only possible when a verbal report is a conscious status of thinking. His point is what if there are some thinking processes impossible to be verbalized? How can the cognitive model based on the verbal report be trusted? In this context, Petrosky’s argumentation is a reasonable claim.

In addition to his critique, there is a similar one pointing out some possible flaws led by using the verbal report. Pierstorff (1981) pointed out, in his analysis of Flower and Hayes cognitive model, that there might be considerably big gaps between the verbalized writing process and the actual writing process. In other words, Pierstorff (1981) said that there may be a quantum difference between the approaches used by that writer who
consciously and vocally observes himself in the act of writing and that one who writes in her normal writing environment, unobserved except by herself. The concerns involved in these critiques add up to one question of if the verbal report can represent the writing process. The critiques pointed that despite the variety of many aspects of the writing process, the verbal report could limitedly reveal some cognitive processes, and Flower and Hayes’ cognitive model, consequently, might not correctly approach to the reality of the writing process.

The review of these debates identifies how important it is to select a data collection method to build a cognitive model. The nature of a cognitive model is shaped depending on what kind of method is employed. The nature of data collection method casts the nature of cognitive model because the model apparently should be grounded on the data source by the method. For instance, Flower and Hayes believed that the best way to model the writing process is to study a writer in action. Thus, to them it was important to capture a detailed picture illustrating the writing process. However, introspective verbal report, which had been used to reveal the writing process, was inappropriate and inaccurate to Flower and Hayes because the introspective verbal report can influence the subjects by directing what should be reported. Also, the introspective verbal report can alter the subject’s thinking process and/or structure; consequently, it is difficult to capture a general thinking process in writing. For this reason, Flower and Hayes decided to use the protocol analysis because it can reveal the cognitive process without changing the course or structure of thinking to write. However, controversies of employing the protocol analysis, like Petrosky (1983) and Pierstorff (1981), insisted that the protocol analysis is not sufficient to reveal some aspects of writing process.

The key issue in these debates is whether a data collection method is valid. The collected data thus represents the phenomenon to model. Flower and Hayes continuously explained the reason of applying the protocol analysis for their study. For their perspective, the writing is a dynamic process of thinking; thus, the best way to identify the recursive nature of writing is capturing what is really happening in a writer’s mind in the action of writing (Flower, 1984; Flower & Hayes, 1980b, 1981, 1985). However, in

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their explanation of applying the protocol analysis, it seems that Flower and Hayes did not make a successful defense against the critiques. Although they noted that there were some limitations in applying the protocol analysis, Flower and Hayes did not show how the limitations could be solved or prevented in their cognitive model. They should have provided a sound rationale of applying the protocol analysis and explained how they analyzed the data with accounting for the limitation. As Cooper and Holzman (1985) pointed out, a more precisely defined specification should have been made to justify how a methodology was appropriate to build a cognitive model of writing.

Constitutions of a cognitive model of knowledge transformation

To make more explicit model specifications of knowledge transformation in authoring hypertext, it should be more precisely clarified what constitutes a cognitive model of knowledge transformation. In general, cognitive theories stress the causal role of mental structures and the process of information (Pintrich & Schunk, 2002). The mental structures refer to an overall framework of cognition. Similarly, two essential assumptions of cognitive theories are representation and process (Haberlandt, 1997). Representation refers to the substantial format of how the content of human cognition exists where the content is assumed as knowledge. Furthermore, it is generally assumed that the representation is formed and processed with an overall framework as a mental structure. From the cognitive perspective, knowledge, as the content of cognition, is not an amorphous substance; rather, it has some structure and format, whether it is a transient image, a memory, the meaning of a word, or a problem to be solved (Haberlandt, 1997). The processing of the information is operating the representation through the mental structure.

In addition, Newell (1994) characterized a cognitive architecture into two crucial features: 1) structure and 2) process. Structure in the human cognition is not a physical property but rather a functional element, which holds information as a representation format. The structure, thus, has to have a fixed element of which constitute itself. Newell
(1994) insisted, “The cognitive architecture is the structure that is fixed while the system produces that performance. Clearly, not all structure is fixed over the course of a performance. Some structure holds the inputs and outputs for each primitive action” (p. 81). Then, each element of the structure has a unique function to execute or operate the representation to process it. Based on the characteristics above, a cognitive model, which this study is pursuing, should consist of the structure and process of cognition in the knowledge transformation process through authoring hypertext documents. Consequently, the structure and process is a framework to integrate the emerged concepts or categories from the analysis.

In summary, a structure, as characterized above, should provide a stable and solid framework of the knowledge transformation process in authoring hypertext document. Also, the structure should be explained as a form of functional elements, which can hold information. It should provide an explanation of how information is getting into the functional element and transferring to another functional element. Specifically, the cognitive model of knowledge transformation should be able to answer what functional elements exist and how they hold knowledge for transformation. Regarding processes by the structure, a process should be a form of description indicating how representations of knowledge are being changed by the functional elements. Furthermore, it should be specified what criteria is involved in executing the representational change.
CHAPTER 3
ITERATIVE MODEL SATURATION PROCESS

Research Design

This study is an inquiry-oriented research to investigate how learners transform their prior knowledge and what cognitive processes are occurring during the hypertext authoring process. Specifically, this study endeavors to construct a cognitive model of knowledge transformation by identifying what cognitive components constitute the knowledge transformation process and how they are structured as a model. Since there has been no systematic scrutiny of the cognitive processes of knowledge transformation in authoring hypertext, an inductive data analysis, a qualitative research method, is employed to theorize a cognitive model of how and/or what cognitive processes are occurring.

To theorize a certain research phenomenon is to generate a new theoretical framework to understand the phenomenon rather than to verify and predict it by existing theories (Creswell, 1998; Savenye & Robinson, 1996; Stebbins, 2001). The theorization process driven by an inductive approach requires an explorative way to analyze research data. For the purpose of this study, given the lack of existing cognitive models of the knowledge transformation in authoring hypertext, the inductive approach is a legitimate way to empirically discover the cognitive components and processes from the data instead of testing the hypothesis. Specifically, this study employs grounded data analysis to theorize a cognitive model of knowledge transformation in authoring hypertext.
Grounded data analysis

Grounded data analysis, also known as grounded theory, provides systematic collection and analysis of data to build a theoretical framework that explains the collected data. Grounded theory, as a method of qualitative research, provides systematic inductive guidelines for collecting and analyzing data. Throughout the research process, grounded theorists develop analytic interpretations of their data to focus further data collection, which they use in turn to inform and refine their developing theoretical analysis (Charmaz, 1995; Creswell, 1998; Strauss & Corbin, 1998). This approach provides the structure often lacking in other qualitative approaches without sacrificing flexibility or rigor. The generated theory is an explanation of categories/concepts, their properties, and the relationships from the collected data (Calloway & Knapp, 1995).

The focus of grounded data analysis is the development or discovery of a theory closely related to the data systematically obtained from the phenomenon being studied. Grounded theorists have formulated rigorous processes of research for generating theory. Grounded data analysis draws out concepts and categories from the data and gradually, through an iterative process, builds up an explanatory framework or theory to explain the events and interactions in the data. Grounded theorists argue that discovery of a theory should be inducted from data, which is a way of arriving at a theory suited to its intended use. From their perspective, a theory should be able to provide clearly described conceptualization of the research undertaking and clear enough categories and concepts to be verified in present and future quantitative studies (Creswell, 1998; B. G. Glaser & Strauss, 1999). Glaser and Strauss (1999) articulated explicit analytic procedures and research strategies toward establishing a theory with a plausible relationship among concepts inductively identified from the data.

This study employs two main techniques of grounded theory: 1) iterative data analysis process, and 2) constant comparative analysis. The iterative data analysis process continuously cultivates the data from the phenomenon of research interests so that the
researcher can get involved in the research context. From the beginning, a researcher actively collects and constructs the data in terms of his or her research interests in order to induct final conceptual units of information until the data is exhaustively analyzed. Along with this procedure, the researcher can identify categories that represent units of information, or concepts. As this iterative process continues, the researcher may explore the same group of participants more deeply or in different ways, or may seek out new groups of participants. The iterative process helps the researcher to theorize a phenomenon being studied.

During constant comparative analysis, while a researcher conducts the iterative analysis process with collecting data, he or she begins constantly comparing the data to illuminate similarities and differences within the data. In the constant comparative method of grounded theory, the researcher gathers information from the field being studied, analyzes it, returns back to the field to gather more information, reanalyzes the data, and revises the theory cyclically until the data is exhausted (Creswell, 1998).

Both techniques, iterative data analysis and constant comparative analysis, enable this study to collect accurate data, specify the concepts of being studied, and yield empirical generalization for a theorized model (B. G. Glaser & Strauss, 1999). First, the techniques can help the researcher collect accurate data by refining the meaning of the data being collected. By conducting iterative data analysis, the researcher is able to discover a more meaningful way to collect data. For instance, he or she can improve interview questions or observation plans to reveal a more meaningful interpretation through the iterative data analysis. Also the researcher may identify how observed data could be differently interpreted by comparing it with another subject/situation so as to clarify how the data should be collected. Categories and/or concepts only acquire their meanings by being respecified with the iterative process of the constant comparative analysis.

Second, the researcher can specify a meaningful unit of information as a concept to be discovered. By applying both techniques the researcher is able to interpret the collected data with multiple perspectives. For instance, along with the iterative data
analysis process he or she is able to realize a more meaningful way to collect data so that the researcher can clarify how the data should be analyzed. Likewise, the constant comparative data analysis helps the researcher discern a different meaning of the given data by interpreting it. Through the techniques, the researcher is able to clarify the distinctive nature of the emerged concepts until clear concepts are reached.

Finally, the iterative analysis process would empower empirical generalization and the explanatory power of the interpretation from the collected data if the researcher could discover consistent similarities and/or differences in his or her data analysis. Likewise, by conducting the constant comparison across the data, it allows richer properties of categories or concepts to emerge from the data as multiple resources.

**Iterative model saturation process: theorizing a cognitive model**

Regarding the benefits of applying the iterative data analysis and constant comparative analysis, this study set three stages to elaborate data collection methods and delineate the cognitive process of knowledge transformation in authoring hypertext: 1) Model Initiation Stage, 2) Model Elaboration Stage, and 3) Model Theorization Stage. These three stages compose the iterative model saturation process of this study, which is based on not only iterative data analysis and comparative analysis but also an evolutionary design approach. Following this process helps a researcher become acquainted to the research context inductively. This evolutionary approach to the study immerses me into the study context so that the resulting theory leads to an evolutionary body of knowledge that is grounded in data. This approach is a zoom-in process when we take pictures to capture a target object. The following three stages of the research design of this study are like taking a picture at a long distance from objects and gradually moving closer to the objects. The iterative model saturation process is illustrated in Fig 3-1.

Along with the Iterative Model Saturation Process, the Model Initiation Stage and Model Elaboration Stage had been conducted within the scope of this research in order to
build and elaborate a sensitizing framework and improve the data collection process. The sensitizing framework is a basic framework highlighting the importance of certain kinds of events, activities, and behaviors.

![Figure 3-1. Iterative Model Saturation Process](image-url)
While the inductive nature of qualitative inquiry emphasizes the importance of being open to whatever one can learn during fieldwork, some way of organizing the complexity of reality is necessary (Patton, 2002). Since this study uses grounded data analysis, creating a sensitizing framework is considered a critical step in obtaining contextual meaning before the main data collection. Also, a sensitizing framework provides me with a general sense of direction with which to examine the data. Furthermore, it can present how the phenomenon is manifest in a research setting (Patton, 2002). The method involves developing categories inductively to provide a starting point for open coding.

Throughout the iterative model saturation process this study established an ongoing model of knowledge transformation in authoring hypertext (See Figure 3-5). Like the analogy of the zoom-in process to take a picture, the on-going model represents how far this study has been developed up to the Model Elaboration Stage. Following the iterative model saturation process has enabled me to improve the validity and reliability of the data collection process and the power of interpretation of the data. The main purpose of conducting the Model Initiation Stage (Ryu, 2002a, 2002b) was to construct an initial model of the knowledge transformation in authoring hypertext. By constructing an initial model, I was able to figure out what cognitive components and processes could be expected and how they should be collected. Then, as a second stage of the iterative model saturation process, the Model Elaboration Stage (Ryu, 2004) was followed to elaborate the initial model so that I could improve the validity and reliability of the data collection process.

**Model Initiation Stage**

**Description**
Participant and research design. As a preliminary stage of the iterative data saturation process, a single subject participated in the Model Initiation Stage. Since this study was focused on transforming prior knowledge, it was necessary to ensure that a participant should be familiar with a given subject matter during the Iterative Model Saturation Process. Therefore, familiarity with a given subject matter was a critical criterion to select a participant. A single participant, who already had taken a class teaching a certain subject matter used on the Model Initiation Stage, was selected. The participant, Chris (a pseudonym), was a male first year doctoral student who has enrolled in a doctoral program of instructional systems. He earned his master’s degree in the same field.

Because the Model Initiation Stage was conducted as a single case study, it was critical for constructing validity and reliability not only to avoid potential misinterpretation but also to maximize the researcher’s data collection (Stake, 1995; Yin, 1993). To ensure the validity of the Model Initiation Stage I used multiple sources of evidence (Yin, 1994), and four sources were analyzed: 1) think-aloud verbal reporting, 2) field notes, 3) open-ended interview, and 4) a hypertext document and a concept map, which were created by the participant.

Triangulation through the four sources was used with the multiple data sources (think-aloud verbal reporting, field notes, open-ended interview, and the hypertext and concept map) to gain unbiased observation, to increase credence in the interpretation, and to demonstrate commonality of an assertion for data source (Stake, 1995). Triangulation helped me avoid from having potentially biased subjectivity in interpreting the data. Regarding a reliability issue, a data collection protocol was developed to increase the reliability of the study in advance of entering the Model Initiation Stage. The protocol includes a procedure of collecting data, and instructions and practice in conducting a think-aloud verbal report.

Material. The subject matter used in the Model Initiation Stage was selected from a class of the theoretical studies of learning and cognition for graduate students. Thirty
concepts were selected from the chapter of “Ausubel’s Meaningful Reception Learning” in the book *Psychology of Learning for Instruction (2nd Ed.)* (Driscoll, 2000).

With the content of Ausubel’s learning and instructional theory, a computer application, referred to as “Knowledge Organizer”, was developed with Toolbook version 5.0. The Knowledge Organizer contained 30 concepts of Ausubel’s learning and instructional theory, and the concepts were presented to the participant in an alphabetical way. Each concept was presented with an identification number on a computer screen. The participant was able to group the given concepts and make links. A user can select several concepts as higher concepts, and then he or she can link other concepts to the higher concepts through the Knowledge Organizer.

**Research setting.** The Model Initiation Stage was conducted in a room equipped with a computer. While Chris was performing a given task, I sat next to him to observe and take field notes. Also, during the entire session of the Model Initiation State, I provided assistance if it was necessary. Two types of assistance were given to the participant. First, when Chris had questions, I provided the answers. In general the participant’s questions were about how to use the Knowledge Organizer. Even though the participant had shown no problems during an instruction session of using the Knowledge Organizer, Chris at times wanted to make sure he was using the tool correctly. Second, I provided prompts to facilitate Chris’ think-aloud verbal reporting. The prompts were given only when the participant did not verbalize his thinking process. To facilitate his verbal report the following prompts were used: “What are you thinking right now?”, “Can you tell me again?” – if Chris made inaudible utterance, “Please verbalize,” and so on.

**Procedure**

First, Chris, the participant, was asked to use a 5 point Likert scale to rate his familiarity with the 30 concepts from Ausubel’s learning instructional theory. The scale ranged from 1 point meaning “not at all familiar” to 5 points meaning “very well
“familiar.” It took 15 minutes to rate all given concepts. The participant rated 17 (57%), 12 (40%), and 1 (3%) of the concepts as very well familiar, familiar, and neutral respectively. Also, Chris reported in the open-ended interview that he had understood the concepts well.

When Chris completed the Likert scale, he received instruction and practice in how to use the Knowledge Organizer. To ensure his confidence level of using the Knowledge Organizer, two work examples were presented, with instruction in think-aloud verbal reporting given before Chris moved on to the second work example. Chris successfully completed the examples without any confusion with using the Knowledge Organizer. During practice with the second work example, Chris was asked to practice think-aloud verbal reporting. While he practiced with the second work example, the following example questions were used to prompt his think-aloud: “Why are you selecting the concept(s)?”, “Describe why you are looking at that concept(s)?”, “What are you thinking about the relationship between the concept(s)?”, and “What does the line mean?” It took approximately 20 minutes to complete the practice with using the Knowledge Organizer and think-aloud verbal reporting, and then a performance task was presented to Chris.

The performance task given to Chris is illustrated in Figure 3-2. As an authoring goal, this task was to have Chris organize the 30 concepts to teach graduate students through the Knowledge Organizer. The target audience of this goal was graduate students in the Instructional Systems program. There was no further information of how many students would be taught, what instructional delivery methods should be used, or how many instructional units should be prepared. The main purpose of this task was to inform the participants of an authoring goal.
The concepts you read in the previous session are a brief explanation of Ausubel's learning and instructional theory. Now, assume that you are going to develop learning material using these concepts to teach graduate students in instructional systems. With this learning goal, please reorganize the concepts as you think it will be most effective to teach your students.

Figure 3-2. Passage of the Problem Statement

Before using the Knowledge Organizer, Chris was asked to draw a blueprint on paper to design how the concepts should be organized into the Knowledge Organizer. Also, he was allowed to modify the plan until he was ready to organize the concepts with the Knowledge Organizer. When Chris completed the organizing process, he was asked to draw his concept map with the thirty concepts. It took 40 minutes to finish the performance task. Then, an open-ended interview followed for 30 minutes. The total time of Chris’ participation in the Model Initiation Stage was 100 minutes.

Data collection

For the Model Initiation Stage four different data sources were used: 1) think-aloud verbal reporting, 2) field-notes, 3) open-ended interview, and 4) the Knowledge Organizer and concept map created by the participant. Think-aloud verbal reporting was used to externalize the participant’s thinking process. Field notes recorded the researcher’s comments during observation. During the participant’s performance, if there were any particular behaviors potentially important for interpretation, I took field notes to describe what a participant was doing. The field notes were analyzed and used as questions for the open-ended interview. An open-ended interview was conducted to
clarify the participant’s utterances that were not clearly verbalized in the think-aloud verbal reporting. For the open-ended interview there were no pre-determined questions. Rather, the questions emerged from the field notes. Finally, the hypertext product and the concept map created by the participant were analyzed to compare how differently a participant represents the relationship between the given concepts.

**Initial model**

An initial model from the Model Initiation Stage is presented in Figure 3-3. The following sections explain how the initial model represents the knowledge transformation process of Chris’ prior knowledge while using the Knowledge Organizer.

**Causal conditions of knowledge transformation.** Two factors were observed as causal conditions that determine the participant’s cognitive process and the consequence of Chris’ knowledge transformation. The causal conditions were 1) the authoring goal and 2) the functions of the authoring tool. They are illustrated as (1) in Figure 3-3. In this study, the authoring goal was to organize the given 30 concepts “to teach graduate students” about Ausubel’s learning and instructional theory (See Figure 3-2). It was important for Chris to arrange the concepts for the purpose of teaching. Therefore, the direction of his knowledge transformation was adjusted by how he believed the graduate students would be able to easily understand the concepts. It was necessary for Chris to reform his knowledge structure for the purpose of teaching. He sorted out the concepts to meet the identified goal, and this cognitive process was similar to the teacher’s transformation process. Teachers do not use their original form of a certain subject content knowledge as stored in their memory but rather reshape the knowledge into a teachable form (Chen & Ennis, 1995). Specifically, Chris was reforming his knowledge structure as a comprehensible structure for the graduate students. The authoring goal was a critical constraint for constructing the given 30 concepts into meaningful format. When Chris used the Knowledge Organizer, he was evaluating whether a concept was
appropriate for the purpose of his authoring goal. Chris considered “…what concept should be placed first…” together with the proper sequence of presenting the concepts.

The second causal condition was how the authoring tool influenced his way of presenting knowledge. When Chris was refining his knowledge structure for the authoring goal, he was considering how he could present his conceptual structure through the Knowledge Organizer as a meaningful structure for his students. This consideration emerged from the open-ended interview questions of how his Knowledge Organizer’s structure was different from his concept map. Because the Knowledge Organizer had a linear way to present concepts, Chris “…needed to fit his knowledge structure into it (The Knowledge Organizer)….” Therefore, when he was authoring with the Knowledge Organizer, he “…had to consider how the Knowledge Organizer could present concepts.”

Figure 3-3. An Initial Model from the Model Initiation Stage
When he was making a blueprint to organize the 30 concepts, he was not yet aware of the functions of the Knowledge Organizer. For this reason, Chris’ blueprint and the Knowledge Organizer had different knowledge representations. This kind of discrepancy occurred when his Knowledge Organizer and concept map were compared. While Chris structured the knowledge hierarchically through the Knowledge Organizer, his concept map was built in an associated form, which was a non-hierarchical structure. It seems that even if Chris’ knowledge of the given concepts was stored in a certain structure at a memory level, he had to rearrange the knowledge structure according to the given functions of the authoring tool. Chris explained the reason as “I did not need to consider how the concepts should be displayed in the concept map”, because he was able to draw any shape of knowledge structure with a pen. It was interpreted that functions of authoring tool regulated Chris’ thinking process in knowledge transformation.

The two causal conditions played a role in building a general guideline of how a new form of knowledge should be organized in a teachable format. The conditions create a trade-off between what would be a meaningful chain and how it should be presented. In other words, when considering the authoring goal, Chris adapted his prior knowledge structure into a different format. The trade-off between the authoring goal and authoring tool’s function can show that design process is more than the process of “a structure adapted to a purpose” (Perkins, 1986) or highly goal-directed process (Rowland, 1993). If there is a regulation of how to present knowledge it should be counted more as a primary factor that affects cognitive processes.

**Prioritizing key concepts.** At a more local level, the causal conditions, authoring goal and functions of the authoring tool influenced Chris to select higher priority concepts as a specific means of reshaping his prior knowledge into a comprehensible form. It is illustrated as (2) in the Figure 3-3. The purpose of the prioritizing process was to chunk some concepts under the prioritized concepts. He compared the concepts to determine where they should be included in an appropriate category as a chunk. During making a blueprint for the Knowledge Organizer, Chris spent much time in determining
which concepts could be chunked within his knowledge structure. As a result, he selected four key concepts that served as the main chunks or categories. Chris verbalized his thoughts during this selection process as follows:

“Actually, I got confused because that concept could belong to another category. However, I thought that I should decide on one category. Sometimes deciding only one category was not easy to do, but it was very important. If I made a wrong category (chunk), my students might have misunderstandings. I just wanted to prevent that kind of situation.” [From open-ended interview]

While using the chunking strategy, Chris categorized with similar concepts. He compared how the concepts could be related to each other.

“I think that number 10 (concept’s number) is closer to that concept rather than this (another concept) one. Is it correct? (Thinking). This one should belong to that category, and it won’t be a problem. Still this concept is unclear.” [From think-aloud verbal reporting]

“Um... Although this concept seems to have a different meaning (compare to a certain category), I bet it is closer to this category.” [From think-aloud verbal reporting]

Tool regulation. There was a regulation of Chris’ thinking process by the authoring tool. It is illustrated as (3) in the Figure 3-3. The functions of the tool were observed to make a significant impact on his cognitive process. Regarding the difficulties of using the authoring tool, Knowledge Organizer, Chris exhibited no problem or any confusion for selecting, organizing, and linking the given concepts. He completed the authoring process without any problems indicating that there was no cognitive overload.
to use the tool. Although the Knowledge Organizer was easy to use, the think-aloud verbal reporting and open-ended interview revealed that the tool was regulating the knowledge transformation process. In fact, Chris made considerable efforts to fit into the function of the Knowledge Organizer while using it to represent his ideas, as he expressed below:

“It may not be a right way of putting this slide. However, this tool (the Knowledge Organizer) just has a linear-way to present information. How can I compromise this problem?” [From think-aloud protocol]

“Sometimes, it was hard to prioritize slides when they do not have a concrete hierarchy. In addition, the authoring tool (Knowledge Organizer) was based on linear navigation, though it had a function to link related information to any higher concept slides. I think that if you add some function of showing non-linear relationship between more than two slides it would be a much better way to convey what I am thinking.” [From open-ended interview]

The discrepancy between the Knowledge Organizer and concept map supported the comments from the think-aloud verbal reporting and the open-ended interview. When Chris was working on the Knowledge Organizer, he constructed a very linearly structured form. However, his concept map showed non-linear directions and dynamic relationships between any single concepts. It may result from a difficulty in developing a technique to represent the learners’ knowledge structure. Although representing the learners’ knowledge structure is very important, finding the technique to do it is challenging (Jonassen, Beissner, & Yacci, 1993).

These preliminary findings may indicate that functions of an authoring tool can regulate knowledge transformation as well as serve as a causal condition of organizing knowledge. In this study, as mentioned early, the authoring tool was designed to produce
a linear-based hypertext product by rearranging the given slides. For this reason Chris needed to fit to the authoring environment. These findings suggest that various ways to represent different characteristics of knowledge should be considered in developing authoring tools.

**Top-down approach.** Due to the regulation by the Knowledge Organizer, Chris seemed to have limited ways of representing his ideas. He used mainly a top-down approach during the authoring process. It seemed that the tool regulation resulted in employing this approach. Also the top-down approach was observed while Chris was prioritizing key concepts. The use of top-down approach is illustrated as (4) in the Figure 3-3.

After Chris first created four chunks, he then located related sub-concepts. During this process, he searched sub-concepts while considering their relevance to the chunks. To determine appropriate sub-concepts, he considered whether the concepts could be related to the chunk. This process can be seen as a subsequent strategy of the prioritizing process. A concept representing a chunk was used as a criterion to evaluate appropriateness of other concepts, reflecting a top-down approach.

“Let’s see, this slide is conceptually higher than number 5 (each slide had its unique identification number)...Oh! This is right. That slide (number 5) is definitely lower than this slide. Then which one can be equivalent with this slide? (Chris is shuffling slides to find another one.) I got it (picking up another slide). Now I need to make sure if these two slides are equally the highest ones.” [From think-aloud protocol]

“Um... Which one should be a first one? This slide or that slide? Let’s see... This should be placed in advance, then that slide should be the second one. (Two slides were already categorized into the same chunk.)” [From think-aloud protocol].
Chris’ process was to determine how well selected knowledge fit each category by searching structural knowledge from a higher level (Eysenck, 1990; Kintsch, 1998). The top-down approach is a conceptually driven processing guided by information already stored in memory. This supports that Chris was already familiar with the content. As an author teaching graduate students about Ausubel’s learning and instructional theory, Chris tried to establish a key structure that could be easily conveyed to them.

Discussion

The Model Initiation Stage revealed two causal conditions of knowledge transformation that constrained the participant’s cognitive strategies. In addition, the Model Initiation Stage identified that the functions of the authoring tool might regulate the transformation process because the participant has to represent his knowledge structure through an authoring tool. Due to the linearity of the Knowledge Organizer, Chris was not able to connect certain concepts with another chunk when the concept did not belong to the chunk. For instance, some concepts may be connected to information in multiple ways.

This Initial Model Stage also raised several questions about using think-aloud verbal reporting as a data collection method. In the Model Initiation Stage it was observed that it was not easy for Chris to perform a concurrent verbal report, think-aloud method, during the task. Three problems were observed: 1) difficulties in full verbalization, 2) quality of the verbal report, and 3) interruption of the performance task. First, the participant, Chris, could not fully vocalize his cognitive process due to the difficulty of the task. Chris frequently discontinued the task performance to vocalize his cognitive process. The difficulty of the task seemed to result from two factors: using the authoring tool and organizing the concepts. Although the authoring tool, Knowledge Organizer, was designed to operate with very simple functions, Chris was sometimes not sure how to use the tool and, thus, stopped his think aloud process. In addition, he felt
difficulties in organizing the concepts for the purpose of the given task even though he was already familiar with the concepts. It was assumed that his difficulties in performing a think-aloud resulted from the task performance, which required higher-order cognitive thinking processes.

Second, there was a quality issue regarding Chris’s think-aloud verbal reporting. This problem was caused by a lack of richness in his think-aloud reporting. It was not easy to analyze in-depth cognitive processes. For instance, Chris usually reported what he was doing rather than what he was thinking. Chris could vocalize what came to his mind regarding performing the task. However, it was not easy for him to vocalize what he was thinking because the participant’s cognitive process occurred mostly at an unconscious level. Specifically, it was hard to capture a vivid thinking process showing why the participant was performing a certain cognitive process for the task.

Third, the task performance was sometimes interrupted due to the cognitive overload of simultaneously performing a think-aloud report and the given task. Two behavioral patterns were often found. First, when the participant concentrated on the task performance, he would not make a verbal report. Second, when the participant was vocalizing his thinking process, he could not perform the task. This interruption possibly made Chris not concentrate on the task.

Besides the issues of applying the think-aloud verbal report, three issues related to chunking process were raised: 1) determining the chunk size, 2) sequencing the chunks, and 3) the role of instructional design skill. First, how did Chris determine the chunk size? Are there any another factors that affected his decision-making about the chunk size? For instance, Chris may have assumed that his target audience, graduate students, had prior knowledge about general theory in learning and instruction. Therefore, Chris may have increased the size of chunks. On the other hand, Chris may have assumed that the concepts about Ausubel’s learning and instructional theory could be easy to learn so that the chunk size would be appropriate for them.
Second, it was unclear how Chris determined a sequence of the concepts through the Knowledge Organizer. This question could be related to his instructional strategies because sequencing learning content is a very important factor.

Last, the Initial Model was not able to explain how Chris’ instructional design skill played a role in the knowledge transformation process. How much did he consider the target audience? What instructional strategy did he want to apply? Although this study did not include the instructional design skill as part of the research frame, identifying the role of instructional design skill would be a valuable factor to develop a cognitive model of knowledge transformation.

Model Elaboration Stage

The Model Elaboration Stage was directed by the questions raised from the Initial Model. Regarding the problems associated with think-aloud verbal reporting, a stimulated recall verbal reporting was considered as an alternative data collection process. The main idea of this method was to show videotape as a stimulus cue to recall participants’ cognitive process after completing a given task instead of using a think-aloud verbal report during performance of a given task. Second, the Model Elaboration Stage attempted to elaborate the Initial Model.

Introduction

Stimulated recall verbal report. To address the previously discussed problems of conducting think-aloud verbal reporting, a stimulated recall verbal report was chosen as an alternative way of collecting data. The purpose of a stimulated recall verbal report is to enable participants to produce more accurate memories of the thinking process with stimulus prompts of their thinking. One benefit of a stimulated recall verbal report is that
a participant concentrates on his/her task performance without interruptions caused by making a concurrent verbal report.

“Stimulated recall methodology can be used to prompt participants to recall thoughts they had while performing a task or participating in an event. It is assumed that some tangible (perhaps visual or aural) reminder of an event will stimulate recall of the mental processes in operation during the event itself. In other words, the theoretical foundation for stimulated recall relies on an information-processing approach whereby the use of and access to memory structures is enhanced, if not guaranteed, by a prompt that aids in the recall of information (Gass & Mackey, 2000, p. 17).”

Applying a stimulated recall verbal report was expected to have several advantages. First, participants would be able to concentrate on their task performance because they do not need to vocalize their cognitive process during the task. As a result, participants would be more involved in the task itself than when they simultaneously perform a think-aloud verbal report while performing the task. Also, participants are able to allocate more cognitive resources on the higher order thinking process of the task by eliminating the simultaneous cognitive work of a think-aloud. Second, participants are able to provide richer information about their thinking process by a stimulated recall verbal report than by a think-aloud. This contributes to forming an accurate understanding of the participants’ thinking process. Finally, task performance is not interrupted.

Elaboration of the initial model. The purpose of the Model Elaboration Stage was mainly to answer the three questions regarding the relationship between cognitive components in the discussion section of the Model Initiation Stage. These questions were 1) determining the chunk size, 2) sequencing the chunks, and 3) the role of instructional design skill. The authoring process requires planning and designing in an organized
fashion for achieving a special purpose (Rowland, 1993). Indeed a design process requires determining and categorizing the systems to be designed (Hubka & Eder, 1987). The design process usually includes creating content, function, and a flowchart (Liu et al., 1998). These activities correspond to the questions of determining a chunk size, the role of design skills, and the sequence within and/or between chunks.

The first step was to answer how Chris determined a chunk size. Specifically, The Model Elaboration Stage attempted to identify what factor(s) influenced the determination of the number of concepts in each chunk. The decision of chunk size provides important information regarding how learners externalize their knowledge to adopt a given authoring goal. The chunk size may be related to a target audience’s knowledge level. For instance, if an author of hypertext perceives a target audience has rich prior knowledge on the content, he or she may increase the chunk size. On the other hand, the chunk size may reflect an author’s perceived knowledge structure of the content. If the author has a big picture of knowledge structure at a more global level, he or she may want to use a different chunk size than one who has a detailed knowledge structure at more local level. More detailed interpretation of the process of determining a chunk size provides a clearer understanding of the cognitive processes involved.

The second step is to answer how the participant decided the sequence of the chunks. Making a sequence represents how the content should be arranged for a target audience.

The third step is to identify how the instructional design skill affects the hypertext author’s understanding regarding the role of design skills in hypermedia authoring. In general, design skills refer to the analysis and identification of needs, definition of goals and objectives, and the design of system components (Perez & Emery, 1995). Unlike the first question of determining a chunk size, this question may be related to a higher level of thinking process monitoring the authoring process. It could provide a more detailed picture of how the causal conditions are being processed. The Model Elaboration Stage attempted to answer these questions to elaborate upon the Initial Model.
Description

Participants. Four participants, three males and one female, were sampled for the Model Elaboration Stage. All of them have enrolled in a graduate program of instructional systems at a southeast public university. Three participants were doctoral students, and one was a master’s student. However, one male doctoral participant’s record of the stimulated recall verbal report was, unfortunately, inaudible. Thus, the data analysis was conducted for three participants. The final participants were two males and one female, and their pseudonyms were Bob, Mike, and Jen respectively.

Material. The subject matter used in the Model Elaboration Stage was the same as that used in the Model Initiation Stage. Again, the content was selected from a class teaching the theoretical studies of learning and cognition for graduate students. Unlike the Model Initiation Stage, the numbers of concepts were reduced to 20 concepts because of the cognitive overload. The concepts were presented to participants in alphabetical way: thus, any predetermined structures of the concepts were not given to participants.

The Knowledge Organizer had been improved to have better interface by using bigger fonts and more consistent screen layout for participants. Providing bigger fonts was to help participants easy to read the concepts and instructions displayed on the screen. Also, using bigger fonts for the Knowledge Organizer would be more helpful for participants to recognize the content of screens when they were verbalizing their cognitive processes while watching the videotape recorded their performance. To increase the consistency of screen layout color scheme was used. The Knowledge Organizer has a series of task to manipulate it. Providing different color scheme would help participants to know what tasks they are doing with the Knowledge Organizer. However, the basic functions of it were the exactly same as the previous one used in the Model Initiation Stage.

Research setting. The research site was equipped with two cameras and one device to record the computer screen as participants interacted with the computer by moving or clicking on the mouse. Two digital cameras were located in the back and side
of a participant. During the observation, the participant followed instructions on the computer screen. I was able to observe the participant’s performance in another room through a one-way mirror. If a participant had any question, he or she could communicate with me through interphone.

In the observation room, there were two monitors displaying the participant’s computer screen and view from the two digital cameras. Also, there was a control unit so that I could switch any visual signal from the computer screen and two digital cameras to two monitors. All data were videotaped.

**Procedure**

The four participants followed a similar procedure as in the Model Initiation Stage. However, they did not use the 5-point Likert scale to measure their familiarity with the concepts. It was assumed that all of them were familiar with the concepts because they took a class on the subject during the previous semester. As a first step, participants received instruction and practice in how to use the Knowledge Organizer. To ensure their ability to use the tool, one example was presented. All of them successfully completed the example without any confusion in using the Knowledge Organizer. Then, instruction in the stimulated recall verbal reporting was presented. Next, they were asked to perform the task. All instructions of procedures were displayed on the screen. They followed the instructions from each screen of the Knowledge Organizer.

The performance task was the same as that in the Model Initiation Stage (see Figure 3-2): to organize the concepts in order to teach graduate students. While using the Knowledge Organizer, the participants followed two steps to organize the concepts. First, the participants were directed to select higher concepts. There was no limit for the number of concepts they could select. Then, they were asked to link the selected higher concepts to another concepts to build links. After finishing the performance task, they watched their videotape recorded during the performance task. In this step, the participants were asked to provide a verbal report. The videotapes served as a stimulated
recall cue. The concept map step was not implemented as in the Model Initiation Stage. It took 70 minutes to complete the process for each participant. The participation time was decreased from the Model Initiation Stage because several steps were omitted in the Model Elaboration Stage.

Data Collection

The Model Elaboration Stage employed three ways of collecting data: 1) field notes, 2) a videotape of participants’ performance, and 3) a videotape of the participants’ stimulated recall verbal reporting. For validity and reliability of analyzing the data, these data sources were triangulated.

Validation of using stimulated recall verbal report

When evaluating the use of stimulated recall verbal report, it was determined to be a better data collection approach than the think-aloud verbal report used in the Model Initiation Stage. It was observed that the participants, Bob, Mike, and Jen, in the Model Elaboration Stage appeared to concentrate more on their performance than Chris did in the Model Initiation Stage, because they did not need to make a verbal report during the performance task.

When Chris was verbalizing his thinking process during the performance task in the Model Initiation Stage he often demonstrated either silence in his verbal reporting or verbal reporting without performing the task. It had been considered that he sometimes could not verbalize and perform the task at the same time because of a high cognitive load. Concurrent verbal reports, think-aloud, have been seen to cause problems when the task involves a high cognitive load (Branch, 2000). Chris’ high cognitive load resulted from performing three mental tasks: 1) the primary task (the given performance task of organizing the concepts), 2) the authoring task (operating the Knowledge Organizer), and 3) the verbalization task (think-aloud task). These three tasks were highly demanding.
cognitive tasks to perform, and thus it was hard for Chris to simultaneously process the three mental tasks. Verbalization requires additional demand for processing cognitive resources to 1) execute motor systems to articulate spoken words, 2) elaborate and monitor verbalization process, and 3) operate oral code as intelligible to other listeners (Russo, Johnson, & Stephens, 1989). In addition to this additional demand, Chris had to operate the Knowledge Organizer. However, the stimulated recall verbal report seemed to decrease participants’ cognitive load during the performance task. Also, when the participants verbalized their thinking processes in the stimulated recall verbal report, there was no difficulty in recalling what they had done. The videotape worked well as a stimulus of the participants’ recall.

Using a stimulated recall verbal report as a data collection method requires accuracy-coherence tradeoff for the data collection for this study. The accuracy refers to how vividly a researcher can capture the cognitive process occurring in participants’ short term memory (STM) by a concurrent verbal report, think-aloud, while the coherence refers to verbalized information by a retrospective verbal report, a stimulated recall. The stimulated recall verbal report has been seen to provide more coherent information of the participant’s thinking process than a concurrent verbal report, though it could be more prone to error if compared to what a verbal reporter actually saw and verbalized (Nielsen, Clemmensen, & Yssing, 2002).

In terms of accuracy, a concurrent verbal report would be more appropriate than a retrospective verbal report like a stimulated verbal report. As insisted by Ericsson and Simon (1993), a concurrent verbal report, think-aloud, should verbalize information only from STM. If a verbal reporter includes his or her explanation based on reasoning, the verbal report is considered an invalid data resource to capture what cognitive process was occurring. This invalidity of think-aloud can happen if there is interruption of the concurrent verbal reporting; then participants may insert their own explanation originated from the long term memory (LTM). When an interruption is made, it leads to a rapid loss of information from STM. Consequently, the loss of information may cause the verbal reporter to verbalize his or her thinking process based on reasoning from LTM. The
reasoning for LTM may not support what is occurring in STM (Ericsson & Simon, 1993; Russo et al., 1989). For this reason, verbal reports of think-aloud are not expected to analyze behavior as in introspection (Katalin, 2000). The verbal report from LTM may not be accurate in analyzing the cognitive process.

On the other hand, retrospective reports may be more coherent than a concurrent verbal report and, therefore, able to give researchers the closest approximation to the actual memory structures because the verbalization process retrieves modified information that may be stored in and retrieved from LTM including instructions remembered, goals formulated, and strategies utilized (Ericsson & Simon, 1993; Pressley & Afflerbach, 1995; Taylor & Dionne, 2000). Although a think-aloud verbal report could, as a concurrent report, provide more accurate information about what is occurring in the reporter’s cognitive process than could a stimulated recall report, applying the concurrent verbal report was not appropriate for this study. First, the tasks require a high and demanding cognitive load and, due to the cognitive load, would hinder participants of this study from concentrating on their performance. Second, the think-aloud verbal report may not be able to reveal detailed cognitive process. Think-aloud reporters tend more likely to verbalize certain types of information, such as goals and the steps taken toward these goals, as compared to the other aspects of the thinking process (Taylor & Dionne, 2000). As identified in the Initiation Model, goal identification plays as one of the causal conditions, and it significantly affects knowledge transformation. For this reason, knowledge transformation with a given goal can be regarded as a goal-oriented mental activity to reshape knowledge to meet the goal. Therefore, if a think-aloud verbal report is applied as a data collection method for this study, it is hard to identify other aspects of the cognitive process, which are not directly associated to goals and steps. For these reasons the stimulated recall verbal report was selected as an appropriate method to collect data for this study.

**Elaborated model**
The elaborated model was delineated to answer the three issues regarding the chunking process raised from the discussion section of the Model Initiation Stage: 1) determining the chunk size, 2) sequencing the chunks, and 3) the role of instructional design skill. Chunk sizes and sequence of the chunks varied among participants in the Model Elaboration Stage. For instance, Bob and Mike made 4-5 chunks while Jen made only 2 chunks. For her chunk size, Jen grouped the given 19 concepts into two chunks, and each chunk was larger in size than were Bob’s and Mike’s. It was obvious that they applied different criteria to determine the number of chunks and the chunk size. The criteria they used would explain what features they considered and what cognitive processes were involved with determining chunks and sequencing the chunks.

An analysis of the Model Elaboration Stage recognized two key factors influencing the chunking process: 1) content knowledge and 2) instructional knowledge. The following section explains how the two factors affect participants’ cognitive processes in chunking the concepts. An elaborated model from the Model Elaboration Stage is presented in Figure 3-4.

**Content knowledge.** The role of content knowledge is illustrated as (1) in the Figure 3-4. When the participants were determining numbers of chunks as well as their size, their decisions were made depending upon their understanding of the concepts. The understanding of the concepts is referred to as the content knowledge, that is a personal understanding of the structures of a subject domain (Chen & Ennis, 1995; McMeniman et al., 2000). In the case of the Model Elaboration Stage, the content knowledge was each participant’s understanding of the given concepts of Ausubel’s learning and instructional theory. Bob, Mike, and Jen seemed to have quite different understanding about Ausubel’s learning and instructional theory.
All of them addressed that they wanted to pick the most important key concepts, but the selections of the key concepts were different. Therefore, the key concepts of Ausubel’s theory might represent that the participants differently perceive the structure of concepts. Referring back to the Model Initiation Stage, the prioritizing of key concepts may be influenced by the content knowledge. In other words, participants’ different content knowledge leads to different prioritization of the concepts.

**Instructional knowledge.** The second factor that emerged was that of instructional knowledge. It refers to instructional transactions and strategies are determined in order to promote a learning process, for example, deciding how to present certain information (Perez & Emery, 1995). Based on different content knowledge, each
participant applied his or her own instructional knowledge to make an optimal structure of the concepts to facilitate learning. All participants explicitly expressed their consideration of the target audience. They wanted to provide the chunks effectively, but their approaches were different. Bob and Mike believed that a chunk size should be small so that learners would not be overwhelmed. Taken from the stimulated recall verbal report, the following quotes indicate the participants’ thought processes:

“I wanted to categorize all concepts into 5 groups because it would be an appropriate structure to teach the concepts. First of all, I tried to make meaningful connections for the concepts. In the meantime, I realized that I tended to make one big chain of the concepts. I thought that there would be too many concepts (to learn) if I made one big chain of the concepts. Thus, I intentionally limited numbers of groups as well as concepts in each group. It was to avoid providing too many concepts (to learners).” [From Bob]

“I thought it would be a good way to categorize similar concepts into several groups (the chunks) for learners. After deciding the higher categories, I linked concepts to the categories (the chunks). I was always thinking how closely a concept is related to the categories.” [From Mike]

For Bob and Mike, the purpose of limiting the chunk size was to help learners understand the concepts by not providing too many concepts at a time. They assumed that if there were too many concepts within a chunk, it would be very difficult for the students to follow. However, unlike Bob and Mike, Jen used a different approach. She was not concerned about the chunk sizes, but was focusing on making a sharp contrast by comparing two key ideas of the given concept of Ausubel’s learning and instructional
theory. For her it was important to provide a simple structure of the concepts. She thought that providing a knowledge structure was more important, as she states below:

(Why did you make only two groups of the concepts?) “I thought of making two groups of ‘rote learning’ and ‘meaningful learning’. I thought that comparing these concepts was a key to teach the concepts about Ausubel’s theory. Once I decided to organize the concepts by comparing two distinctively different ideas, and then I looked through all concepts. During looking the concepts, I was thinking which one was similar either ‘rote learning’ or ‘meaningful learning’.” [From Jen]

Instructional knowledge was also observed to influence a sequence of the chunks. Two interesting approaches were found: 1) the comparative approach and 2) the additive approach. First, Bob and Jen used the comparative approach to sequence the concepts. Bob looked through the concepts to find how they were different between the chunks. He seemed to try to make a meaningful comparison between chunks. Jen also used a comparative strategy to provide a simple structure to deliver the concepts of Ausubel’s learning and instructional theory.

“ I tried to arrange each concept group (chunk) to show differences between the concepts. Since each concept group had similarities, I needed to show how the groups were different. By showing the differences between concept groups, it would be easy to make a knowledge structure about Ausubel’s learning and instructional theory.” [From Bob]

“I just wanted to compare how two concept groups (‘rote learning’ and “meaningful learning”) were different. [Researcher: How did you
arrange them? Is there any criterion to sequence them?] Well, no I did not have that. But, comparing two different ideas would be good for the learners.” [From Jen]

Second, unlike Bob and Jen, Mike arranged the concepts from the easiest concept first to the more complicated. His approach was labeled as an additive pattern. This is to move learning contents from the easiest to the most complicated.

“How did I arrange them? I put fundamental concepts first...and from there, on to the more complicated. I was thinking what would be a better design.” [From Mike]

No matter what approaches they applied to sequence the chunks they seemed to have the same purpose: to effectively present the chunks for the learners. The efforts to make an effective presentation of the chunks were made to promote a learning process. It was identified that the participants’ instructional knowledge affected the determination of chunk sizes and the sequencing of the chunks.

Consequence of instructional knowledge. The participants’ instructional knowledge seemed to have an overall effect on determining chunk size and sequencing the chunks. Consequently, the instructional knowledge can be interpreted as a process of making “teachable units” and a “teachable structure”, which are illustrated as (3) in the Figure 3-4. The teachable units represent the meaningfully manageable chunk sizes for learners. The teachable units could be determined by a consideration for learners’ capability to handle the chunk size, as Bob and Mike did, or one could consider a conceptual structure to promote learning the chunks, as did Jen. Also, the teachable structure refers to a way of effectively delivering the chunks. It mainly focuses on how to present the chunks to learners as an instructional strategy.

The participants were considering how the concepts should be organized in an effective way. Along with the effectiveness of presenting the chunks, Bob and Mike
wanted to limit the sizes of the chunks for learners. Jen wanted to provide a conceptual structure about Ausubel’s theory though she was not concerned about the chunk sizes. For her, the teachable sizes of the chunks were a matter of a conceptual structure of the given concepts. In addition, instructional knowledge also affected sequencing of the chunks. Participants seemed to try to construct a teachable structure of the chunks they made as a way of presenting them to learners.

Discussion

Content knowledge and instructional knowledge emerged as factors from the Model Elaboration Stage. Specifically, it was revealed that the process of organizing concepts would vary based on the content knowledge of how a person perceives a body of knowledge to be transformed. Instructional knowledge was identified as having an overall effect on determining chunk sizes and sequence. As a result, instructional knowledge affects the determination of teachable units and teachable structure.

However, there are three questions that still remain unanswered from the Model Elaboration Stage. First, how does interaction with the authoring tool affect knowledge transformation? This question considers the relationship between authoring tool functions and cognitive processes of the knowledge transformation. The Model Elaboration Stage has investigated how the authoring functions of the Knowledge Organizer related to the cognitive processes when participants were applying their instructional knowledge. Since it was assumed that an authoring tool’s function is to facilitate the externalization of the user’s knowledge, the externalization of the knowledge may directly relate to deciding on an effective delivery method for the chunks as a part of the function of the instructional knowledge.

Second, what are the cognitive strategies being used in the knowledge transformation process? The Model Elaboration Stage could identify several components of knowledge transformation. However, it did not successfully identify specific cognitive strategies. For instance, Bob seemed to use a reviewing strategy as his cognitive process
to make a meaningful chunk by stating, “I looked back.” Jen seemed to use a comparing strategy to articulate her conceptual structure of the given content. Indeed, Mike seemed to apply an elaborative strategy to make a sequence of the chunks from the easiest to most complex. The detailed cognitive strategies should be illuminated to construct a cognitive model of knowledge transformation.

Finally, what are the specific roles of the participants’ instructional knowledge? From the Model Elaboration Stage, the content knowledge and instructional knowledge emerged as factors. Indeed, it was identified that the instructional knowledge transformed the content knowledge through knowledge transformation. It should be considered that if the content knowledge has been transformed for the purpose of the goal, what then would be the specific roles and/or nature of the instructional knowledge? Identifying what, if any, differences exist between the content knowledge and the transformed knowledge would provide a more powerful explanation of the role of the Knowledge Organizer as a tool of transforming and externalizing knowledge. These questions are further explored in the Model Theorization Stage.

**On-going Model**

The results from the Model Initiation Stage and Model Elaboration Stage were integrated in a conceptual model illustrated in the Figure 3-5. Several key components emerged as factors in an on-going model of knowledge transformation through hypertext authoring.

**Content knowledge**

It was observed that participants had different understanding of the concepts as their content knowledge illustrated as (1) in Figure 3-5. In the knowledge transformation
process the content knowledge is not only a source of knowledge to be transformed but also a personalized mental representation of the knowledge (Chen & Ennis, 1995; Moallem, 1998).

Specifically, the content knowledge is internally modified to meet the given goal. However, because of the different content knowledge for each participant, when participants were prioritizing key concepts to build chunks, they made different selections by referring to their content knowledge. The differences between their content knowledge seemed to yield different approaches to selecting chunks. That is, the internally modified representational structures for the same goal would vary based on how the content knowledge differed.

**Causal conditions**

There were two causal conditions influencing cognitive processes in hypertext authoring. They are illustrated as (2) in the Figure 3-5. The given goal (See Figure 3-2) played a role in determining how to organize the concepts. The main objectives of the goal were “to develop a learning material” and “to teach graduate students.” By identifying the two objectives, the participants’ content knowledge was modified to meet the objectives. Also, the functions of the Knowledge Organizer played a role in regulating how to present the modified content knowledge. In other words, the given goal affects internal modification of the content knowledge.

The functions of the Knowledge Organizer influence the externalization of the modified content knowledge. Although the roles of the goal and authoring tool’s function are different, they are not working discretely but mutually. The mutual relationship yields a reconstructive mental process between goal identification for internal modification and the tool’s function for external representation in order to transform the content knowledge.
Figure 3-5. On-going Model of Knowledge Transformation
**Internal modification of content knowledge**

In the mutual relationship between the authoring goal and tool, the authoring goal would be a crucial starting point in leading to an internal modification of knowledge transformation. This is illustrated as (3) in Figure 3-5. As a design process, the mental process of knowledge modification is an intensive goal-oriented activity of changing an existing situation (knowledge structure) to achieve a desired result (R. Glaser, 1976; Rowland, 1993). The participants of the preliminary stages firstly set and identified the given goal of organizing the concepts of Ausubel’s theory for their peers as learners. The initial activity of goal identification is quite similar to what instructional designers do in their design process. “(The designers) broadened the planning phase by including the identification of tasks to be taught,” (Perez & Emery, 1995). “(The designers) engaged in goal directedness,” (Perez, Johnson, & Emery, 1995).

**External representation by tool regulation**

The function of an authoring tool is to regulate the participants’ authoring process as a way of externalizing the modified representation structure. This is illustrated as (4) in Figure 3-5. As a tool of externalizing knowledge, participants should follow the ways of presenting their knowledge given by the tool. While goal identification changes a mental representation to meet a purpose, the authoring tool’s function is to present the mental representation. Therefore, the mental representation would likely be altered by those ways an authoring tool allows the presenting of knowledge. In other words, an author may modify his or her needs and goals according to the capabilities and limitations of a given technology (Waycott, 2001). Therefore, if there are any limitations of an authoring tool in externalizing someone’s knowledge structure, authors determine how their knowledge transformation should be restructured through the use of the authoring tool, as in the concept of tool mediation originally proposed by Vygotsky (Belisle et al., 1997; Colbourn, 1995; Waycott, 2001). From this perspective, cognitive transformation
should be brought on by the cognitive artifacts of authoring hypertext. For these reasons, goal identification and functions of an authoring tool serve as causal conditions of knowledge transformation through authoring hypertext.

**Instructional knowledge**

Last, the existence of instructional knowledge was observed. Participants applied instructional knowledge to determine chunk sizes and sequence. The ultimate goal of using instructional knowledge was to organize the content knowledge into meaningful units and to create effective presentations. In other words, instructional knowledge transforms the content knowledge into a teachable form to facilitate learning (Chen & Ennis, 1995). Consequently, the use of instructional knowledge transformed the content knowledge in terms of teachable units as meaningful chunks and a teachable structure as an effective presentation.
CHAPTER 4

METHOD OF MODEL THEORIZATION STAGE

Participants

Six Korean students participated in the Model Theorization Stage. They are enrolled in a doctoral program of instructional systems at a southeast public university. Two sampling techniques were used to select the participants: 1) criterion sampling and 2) theoretical sampling.

Criterion sampling

Criterion sampling involves selecting samples that meet criteria for the purpose of study. In terms of quality assurance, this method of sampling is very strong, particularly for a qualitative study because it enables researchers to focus on a certain phenomenon being studied (Creswell, 1998; Patton, 2002; Strauss & Corbin, 1998). For this study, three criteria were set in terms of 1) instructional design skill, 2) prior knowledge, and 3) primary language.

First, the instructional design skill of participants should be similar. Authoring hypertext documents may depend on the person’s instructional design knowledge. For instance, there is a quite a different process for designing instructional materials between a novice and an expert (Perez & Emery, 1995; Perez et al., 1995). The design process is affected by the designer’s knowledge, skill, and experience (Rowland, 1993). This study
focuses on how a participant transforms his or her knowledge through authoring a hypertext document. Thus, the participants’ instructional design skill should be controlled to ensure similar knowledge levels of instructional design theory. Six participants were selected from graduate students. They were two males and four females. Five participants were doctoral students, and one was a master’s student.

Second, participants should have prior knowledge of Ausubel’s learning and instructional theory. Since this study’s goal was to identify a cognitive model of knowledge transformation rather than a model for knowledge acquisition, it was critical to ensure that all of the participants had previously studied Ausubel’s learning and instructional theory. In addition, the level of understanding of prior knowledge was also important because it could affect their interpretation and organization of the contents (Driscoll, 2000; Jonassen et al., 1993). Because this study was not a comparative research to identify how different levels of understanding affected a transformation process, it was also important to control participants’ understanding at a similar level. An instrument to measure prior knowledge was administrated before conducting a main phase of the Model Theorization Stage to ensure participants’ prior knowledge.

Third, participants should be able to speak Korean as their primary language as well as have grown up in Korean culture. This criterion was set up because of the researcher’s primary language and cultural background. Because this study was mainly based on observation, verbal reports, and interview of participants, communication and understanding between participants and me was the critical factor in analyzing and interpreting the collected data. It was crucial for me to have an in-depth understanding of the meaning of a certain situation as a form of mutual interaction of culture and language (Frow & Morris, 2000). There were some special words and ideas that simply could not be translated directly. These unique meanings could be interpreted only by one who has understanding of the cultural meaning of the special terms (Patton, 2002).

In addition to the issue of culture and language in the selection of participants, there was another aspect to consider. The interpretation of the participants’ gestures and facial expressions was also related to the issue of culture and language. During the
observation of the performance task, the participants’ interaction with the authoring tool was videotaped as one of the data resources. Consequently, nonverbal communication was analyzed as well as verbal communication. During the performance task, participants showed gestures as nonverbal communication. The interpretation and understanding of nonverbal communication required meaningfully situated understanding because nonverbal cues conveyed highly symbolized meaning in culture and language. Indeed, since the observation included an analytical description of facial expression, cultural understanding was critical in analyzing the collected data.

I had experienced these culture and language issues during the Model Elaboration Stage. In the Model Elaboration Stage English was used to communicate with one non-Korean participant. When the participant’s verbal protocol was transcribed, I experienced that it was hard to capture dynamic and vivid expressions in the participant’s verbal report. Also, it was not easy to interpret some nonverbal communications such as facial expressions and body gestures. However, the observations for Korean participants in the Model Elaboration Stage delivered relatively precise meanings corresponding to the context. Furthermore, I could obtain better and deeper understanding. For these reasons, the third criterion was set to select Korean graduate students as participants for the Model Theorization Stage.

**Theoretical sampling**

A theoretical sampling technique was used to determine a specific number of participants. This sampling is particularly useful when exploring new or undiscovered research interests because it enables me to determine who or what is able to provide the most theoretically saturated model (Strauss & Corbin, 1998). During the Model Initiation Stage and Model Elaboration Stage, four students participated and were analyzed. Following the Iterative Model Saturation Process, I has become familiar with the research context. Thus, it was estimated that six participants would be sufficient for this study to validate the results from the Model Initiation Stage and Model Elaboration Stage.
Research Setting

The research setting of this study was a computer and video recording observation room in the “Usability Center” located in the College of Information Studies at a southeast public university. The Usability Center was founded to evaluate computer software usability, that is, to test how easily computer software could be used. It had facilities to conduct, observe, record, and analyze usability evaluations. The research setting was 300 square feet consisting of two rooms, the evaluation room and the observation room. Figure 4-1 and 4-2 show the evaluation room and observations room respectively.

Evaluation room

In the evaluation room, there were several devices to monitor a user’s interaction with a computer. First, there was a desktop computer operating Windows 98™ with a 17” color monitor. The computer was connected to a Hyper Converter™ that sent video signals from the monitor to a control unit in the observation room, which was separated from the evaluation room by a one-way mirror. The control unit recorded pictures from digital cameras and the computer.

The participants’ operation of the computer was converted into video signals through the Hyper Converter™, and then the control unit recorded the signals on videotape. Also, the computer had a sound system and a mouse. There were two digital cameras to videotape user’s gesture and behavior while a participant operated the computer.
Observation room

The observation room was located next to the evaluation room with a one-way mirror between the rooms. I stayed in the observation room while a participant was performing the tasks of this study. Through the one-way mirror I could observe the participants’ behavior. Use of the Knowledge Organizer was observed and recorded through a control unit. The control unit had video converting switches to record one of three video signals from the computer screen and the two cameras in the evaluation room. Also, the video converting switches had a Picture in Picture (PIP) function displaying a small screen while another screen was displayed as the main screen. From the experience of Model Elaboration Stage using this PIP function could provide more stimulus cues for a participant’s stimulus recall verbal report. Figure 4-2 shows the observation room.
The participants’ stimulated recall verbal report was conducted in the observation room. Two camcorders were used to videotape the participants’ verbal reporting process. One camcorder recorded a participant’s face and body gestures during the stimulated recall verbal report. Another camcorder recorded the TV monitor displaying the videotape of a participant’s performance while performing the task. Using two camcorders enabled me to collect richer data during the participants’ stimulated recall verbal reporting.

Figure 4-2. Observation Room

Screen format of video recording as a visual cue
The screen format of the video recording was important as a visual cue to prompt the participants’ recall. The purpose of showing the video recording was to reactivate or refresh the recollection of cognitive processes so that participants could accurately recall and verbalize (Gass & Mackey, 2000). The more stimuli on the screen was able to provide, the more participants was helped to recall and verbalize the cognitive processes involved with their performance of the task.

There were three devices to videotape the participants’ behavior: one computer screen and the two digital cameras in the evaluation room. Also, the control unit in the observation room could record two screens at the same time by using the PIP function. The computer screen showed how the participant was operating the Knowledge Organizer. Two other screens from two digital cameras showed the participant’s body gestures.

It was observed that participants in the Model Elaboration Stage (Ryu, 2004) tended to recall more when the recording of the computer screen was displayed as a main screen while a small screen replayed images captured by the cameras, as depicted in Figure 4-3. Providing the computer screen as a main screen facilitates the participants’ recall of their cognitive processes. For instance, when a participant in the Model Elaboration Stage watched a video recording showing the computer screen only, he or she frequently was silent because there was no adequate stimulus cue of what content he was examining. As one participant in the elaboration stage stated, “I have no idea what I was doing”.

However, the participants’ gestures and facial expressions also played a key role in providing additional cues when their memory was vague. The participants’ gestures and facial expressions were very helpful in reminding participants of what they were thinking. A nonverbal expression, such as one of confusion, may trigger the participant’s recollection of their emotional status and their corresponding thought processes. Figure 4-3 illustrates how the participants’ behavior was videotaped, and it was the basic screen format for the Model Theorization Stage during their verbal reporting.
Materials

Subject matter

Thirteen concepts of Ausubel’s learning and instructional theory were given to the participants. The concepts were listed in Appendix A. These concepts were selected from a textbook titled *Psychology of Learning for Instruction* (Driscoll, 2000), which is currently used for one of the required courses in a graduate program of instructional systems at a southeast public university.

To select the concepts, two considerations were taken into account. First, the contents should be common concepts for participants. Ausubel’s learning and instructional theory is a standard part of educational practice in the instructional design
field (Driscoll, 2000). Thus, his theory can be regarded as a core content for those who are majoring in instructional systems. Second, the content should not be too easy. If it is too easy, participants can use their general knowledge of learning and instructional theory to perform the tasks rather than use the specific knowledge of Ausubel’s theory as prior knowledge to be transformed. Although Ausubel’s learning and instructional theory is regarded as core knowledge in instructional design theory, the theory is complex, requiring broad understanding across learning and instructional theories. However, even after selecting the content, the difficulty of the content should be carefully calibrated. If the content was too difficult and detailed, the participants could be frustrated. Also, it was important to prevent participants from experiencing cognitive overload. From the Model Initiation Stage and Model Elaboration Stage it was observed that some participants were cognitively overloaded because of the difficulties of understanding the content.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Words</th>
<th>Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>49</td>
<td>289</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>54</td>
<td>328</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>47</td>
<td>274</td>
</tr>
<tr>
<td>Discovery Learning:</td>
<td>54</td>
<td>313</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>48</td>
<td>318</td>
</tr>
<tr>
<td>Learning Material</td>
<td>49</td>
<td>273</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>53</td>
<td>300</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>52</td>
<td>318</td>
</tr>
<tr>
<td>Readiness</td>
<td>48</td>
<td>300</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>51</td>
<td>288</td>
</tr>
<tr>
<td>Retention</td>
<td>49</td>
<td>282</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>52</td>
<td>281</td>
</tr>
<tr>
<td>Understanding</td>
<td>49</td>
<td>287</td>
</tr>
</tbody>
</table>
Regarding the issue of cognitive overload for participants, two aspects were considered: 1) the difficulty of the concepts and 2) the number of concepts. To address the issue of the difficulty of the concepts, the entire chapter about Ausubel’s learning and instructional theory in the textbook (Driscoll, 2000) was reviewed, and then some concepts were selected from a sub-chapter of “Meaningful Reception Learning.” The sub-chapter about meaningful reception learning was evaluated as introducing Ausubel’s basic concepts. It was also assessed as not too difficult. The numbers of concepts were adjusted to thirteen concepts.

The original texts of the thirteen concepts were modified to make the length of description of the concepts balanced. It was important to provide similar lengths of the concept descriptions to ensure that participants had comparable time to read about each concept. In order to make sure whether the concepts were properly shortened or extended from the original text (Driscoll, 2000), the concepts were verified with the author of the textbook. Finally, the readability test of the concepts considered the word and character counts. The mean of the word and character counts of the concepts were calculated at 50.39 and 296.23 with standard deviation of 2.40 and 18.12 respectively. Table 4-1 shows the word and character counts.

**Knowledge organizer**

The Knowledge Organizer, an authoring tool developed by the researcher, was used for this study. I developed the Knowledge Organizer by using ToolBook II Instructor 5.0.

**Phases of the knowledge organizer.** The Knowledge Organizer consisted of three phases to guide the participants: 1) the introduction, 2) the instrument, and 3) the performance task. When participants started the Knowledge Organizer, it provided the overview of the study, procedure, and stimulated recall verbal report. Each introduction was presented on a screen, and participants could navigate to a next screen only when they clicked a next button on the screen. The overview was to introduce a general
purpose of this study. The introduction of procedure was to inform participants what tasks they would do during their participation in the Model Theorization Stage. The introduction of the stimulated recall verbal report was to instruct participants how to perform the verbal report. It also notified the participants that they would be videotaped during their performance. During this first phase of the introductions, three screens were presented to participants.

![Sample Screen of the Instrument Item](image)

**Figure 4-4. Sample Screen of the Instrument Item**

When participants completely read the introductions, an instrument was presented for the second stage. This instrument was to measure the participants’ familiarity with and understanding of the 13 concepts of Ausubel’s theory. Each instrument item had two
questions, and the questions were asked of participants to measure their familiarity with and understanding of the concepts: 1) the familiarity question, “Have you seen this concept before?” and 2) the understanding question: “Do you understand the concept?” Each question was rated with a 5-point Likert scale, with 1 meaning “not at all” through 5 meaning “very well”. The purpose of asking two questions was to ensure how well participants knew the concepts. Figure 4-4 illustrates an example. Participants could go to the next instrument item only after rating the two questions. All screen captures of the instruments were shown in Figure B-5 through B-13 of the Appendix B.

The third phase was the performance task. This phase started with a problem statement screen, the authoring goal (See Figure 4-5). The goal consists of the following components and the brackets corresponded to the sentence in Figure 4-5: 1) content area [the concepts of Ausubel’s learning and instruction theory], 2) task [reorganize the concepts to teach graduate students], 3) target audience [graduate students do NOT have prior knowledge], and 4) final outcomes [learning material, the most appropriately effective to teach the students.]

The last paragraph in the problem statement screen of Figure 4-5 instructed participants in how to use the Knowledge Organizer. It consisted of three steps: 1) select key concepts, 2) sequence the selected key concepts, and 3) link other concepts to key concept as subordinate concepts. In the selection of key concepts, participants could choose any concepts as key concepts. There was no limitation on the number of concepts to select. Once selecting key concepts, participants could rearrange the selected key concepts into what they consider to be the best order. Then, participants were asked to link other concepts to the selected key concepts. The following three sections provided more specific descriptions and functions of the three steps.
The concepts in the previous session are from Ausubel's learning and instructional theory. Now, you are going to reorganize the concepts to teach graduate students.

The purpose of this task is to develop learning material for the students. Suppose that the students are first-year master students who want to take a class of learning and instructional theory. Also, they do NOT have prior knowledge of Ausubel's theory. In other words, they are novices in the concepts you have read in the previous session. Therefore, the learning material you will be developing should be appropriate for their knowledge status. Please reorganize the concepts as you think it will be most appropriate and effective to teach the students.

You will follow three steps for this session. First, you will be asked to select several concepts as chapter headings of your learning material. In this step you do not need to think about how the chapters should be sequenced. For the second step, you will have to make an appropriate sequence for the chapters. For the third step, you will link concepts to the chapters. More detailed information will be displayed in the following screens. If you are ready to go, click the BLUE button.

Figure 4-5. Passage of the Problem Statement in the Knowledge Organizer

Functions of selecting key concept. This screen had six components: 1) instruction, 2) concept list window, 3) content viewer, 4) add-and-drop button, 5) result window, and 6) navigation button. Figure 4-6 is a screen capture of the select key concepts. The instruction showed what participants could do in the screen. The concept list window explained what concepts were left to select. Participants could either see the descriptions of concepts or select one concept from this list. When a participant clicked one concept of the concepts list, the corresponding description was displayed in the content viewer. The function of the add-and-drop button was to either select a concept
from the concepts list or deselect it. Once a concept was added, it moved to the result window. The function of the navigation button was to go to the next screen.

**Figure 4-6. Components of the Select Key Concepts**

**Sequence the selected key concepts.** The functions of this screen were similar to the select key concepts, and there were five components in this screen: 1) instruction, 2) list of selected concepts, 3) content viewer, and 4) navigation button. They were illustrated in Figure 4-7. The functions of 1), 3), and 5) were the same as the select key concepts. The list of selected concepts displayed the names of the concepts that were
selected in previous screen. Participants could use a mouse to change the sequence of the selected concepts by dragging a certain concept.

![Diagram of Make the Sequence of Chapters screen]

**Figure 4-7.** Components of the Sequence the Selected Concepts

**Link other concepts to the key concepts.** The functions of this screen were similar to those of the select key concepts with eight components. Among them, numbers 1, 2, 3, 4, 5, and 8 were the same functions explained in the select key concepts. Number 6, the link-and-drop button, was to link sub-concepts to the selected key concepts. The linked sub-concepts were displayed in the link window illustrated as number 7 in Figure 4-8.
Generating hypertext. When participants finished linking other concepts to the key concepts, the Knowledge Organizer generated the hypertext that the participants organized. The key concepts were displayed as main slides, and each of the main slides had links with related sub-concepts. Figure 4-9 shows a sample screen of hypertext by the Knowledge Organizer. This sample screen presents an example that the “Assimilation Theory” was selected as one of the key concepts. Five components consist of the screen. Numbers 1 and 2 in this figure are for the title and content of the concept. Participants could type a self-description to explain in the text box of number 3 why he or she linked the concepts there. The linked concept(s) were displayed in a small window illustrated as

<table>
<thead>
<tr>
<th>Direction</th>
<th>Selected concepts</th>
<th>Content viewer</th>
<th>Concept list</th>
<th>Content viewer</th>
<th>Link/Drop button</th>
<th>Link window</th>
<th>Navigation button</th>
</tr>
</thead>
</table>

Figure 4-8. Components of the Link Screen
number 4, below the self-description box. This example figure 4-9 represents that only “Meaningful Learning” is linked to “Assimilation Theory”. Also, navigation buttons were displayed in a right button of the screen (For a more detailed example of generating hypertext, see Appendix C).

![Sample Screen of Hypertext by the Knowledge Organizer]

<table>
<thead>
<tr>
<th>①</th>
<th>Key Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>②</td>
<td>Content of the Concept</td>
</tr>
<tr>
<td>③</td>
<td>Self-description</td>
</tr>
<tr>
<td>④</td>
<td>Linked other concepts</td>
</tr>
<tr>
<td>⑤</td>
<td>Navigation button</td>
</tr>
</tbody>
</table>

**Figure 4-9. Sample Screen of Hypertext by the Knowledge Organizer**

**Concept map builder**

When participants finished the Knowledge Organizer, they were asked to build their concept map of the given concepts using the Concept Map Builder. The purpose of
using the Concept Map Builder was to visualize the participants’ knowledge structure of the given concepts without a goal of knowledge transformation.

Now you will be asked to make a concept map of the concepts of Ausubel’s learning and instructional theory. The purpose of this session is to ask you draw your knowledge structure of the concepts. In other words, its purpose is to show how the concepts are interrelated in your mind. When you perform this session, please do NOT think about creating learning material to teach the concepts to graduate students.

In this session, all thirteen concepts will be displayed as small text boxes. By using your mouse, you can move them to any place as you want. Once you move the concepts, you need to draw a line to indicate how they are linked.

To draw a line between two text boxes, double click on the first text box as your starting point, and then double click on the second text box as your destination of the line. Then, this program will draw a line between the two text boxes. If you want to remove any line, place a mouse cursor on the line and click the right button of the mouse. Also if you want to restart making a concept map, you can do it by clicking the RESET button.

Figure 4-10. Passage of the Problem Statement in the Knowledge Organizer

Unlike the Knowledge Organizer, the Concept Map Builder did not require selecting higher concepts and sequencing them. The purpose of the Concept Map Builder was to identify how differently participants would structure the concepts when they did not have an authoring goal such as organizing the concepts for the instructional purpose of creating learning material using the Knowledge Organizer.
The Concept Map Builder was also developed with ToolBook. Participants could build their concept map by mouse dragging. Figure 4-10 shows a passage of the Concept Map Builder. The passage was designed to provide information of how to use the Concept Map Builder. When participants went to the next screen, an example of a concept map was provided to help them see what their concept map would look like. Figure 4-11 shows a main screen of the Concept Map Builder.

Figure 4-11. Main Screen of the Concept Map Builder

The Concept Map Builder consisted of five components. When participants moved a mouse on any of concepts, the description of the concept was displayed in the
content window. Participants could move the concepts to any place on the screen, and they could make and remove a line between two concepts by double-clicking. While building a concept map, if participants wanted to restart the building process they could return back to the initial mode by pressing the reset button on the main screen. When participants finished building the concept map, they could go to the next screen by pressing the next button. In the next button, participants were asked to describe what they considered in building the concept map. The screen captures of the Concept Map Builder were presented in Appendix D.

Performance Tasks

Participants engaged in three main performance tasks: 1) organizing concepts using the Knowledge Organizer, 2) building a concept map, and 3) reporting a self-description.

Organizing concepts

Participants in this study were given thirteen concepts of Ausubel’s learning and instructional theory. The concepts were describing some key ideas of Ausubel’s theory. The participants were asked to develop learning material to teach graduate students about the concepts of Ausubel’s theory. The purpose of this task was to provoke the participants’ higher-order thinking. To organize the given concepts the participants had to interrelate, rearrange, and/or group them to create instructional material. Then, creating instructional material was a goal for the participants to achieve. In addition, they had to create the instructional material by using the Knowledge Organizer. The result of using the Knowledge Organizer was a product, which might be delivered as an instructional material to teach the given concepts. It was assumed the participants were familiar with
the concepts as their prior knowledge. Since the Knowledge Organizer was developed to help participants organize the given concepts, there was no function of creating new concepts with the Knowledge Organizer.

Although the Knowledge Organizer did not have the additional functions of the other authoring tools like HyperCard, HyperStudio, ToolBook, Authorware, etc., use of the Knowledge Organizer still placed cognitive demands on the participants to organize the concepts to create instructional material. The purpose of organizing the given concepts was to convert information in the form of instructional material into information in the form of specifications (Rowland, 1993). Thus, authoring concepts played a role in giving a problem-solving situation to participants. The participants’ performance in authoring concepts consisted of a set of cognitive efforts to transform their prior knowledge into the specific forms of the Knowledge Organizer. With these circumstances the participants’ higher-order thinking would be involved with inference, interpretation, analysis, judgment, active mental construction, and synthesis (Maor & Knibb, 1999). While working with the Knowledge Organizer, the participants’ behavior was observed and videotaped, including all interactions with the computer.

**Concept mapping**

As a second task, the participants were asked to build their conceptual structure of the given concepts. The purpose of this task was to identify if there was any difference between organizing the concepts and their conceptual structure. A concept map was a two-dimensional diagram that was illustrating relationships between ideas in a content area. It was organized hierarchically. In general, higher concepts would be placed at the top of the relationships, and detailed concepts lower on the hierarchical structure (Jonassen et al., 1993). According to the Initial Model Study (Ryu, 2002a, 2002b), the participant of the study built a concept map with a different structure as a result of the Knowledge Organizer. It was assumed that the difference in structure between the
Knowledge Organizer and concept map could reflect the role of the authoring goal and/or the authoring tool while organizing the concepts.

**Procedure**

The Model Theorization Stage was conducted through the nine steps of Figure 4-12. Video recording of the performance tasks started from step three, the instrument, and continue to step seven, the self-description of the concept map. Also, steps eight and nine were videotaped for data analysis. Field notes were taken from step four, organizing concepts, to step seven, self-description of the concept map.

**Data Sources**

The analysis results of the Model Elaboration Stage were used to determine what data should be collected and analyzed. Three questions were raised: 1) “How did the interaction with the authoring tool affect the knowledge transformation?”, 2) “What were the cognitive strategies being used in the knowledge transformation?”, and 3) “What were the specific roles of the instructional knowledge?” The data sources for the Model Theorization Stage were determined in order to answer these questions. Five data sources were used: 1) stimulated recall verbal report, 2) self-description, 3) interview, 4) interaction with the Knowledge Organizer, and 5) artifacts of the Knowledge Organizer and Concept Map Builder produced by the participants.
Although all of the data sources were analyzed to build a cognitive process of knowledge transformation, some data sources specifically were used to answer the three questions above. First, the self-description and interview were more focused on answering the second question: “What are the cognitive strategies being used in the knowledge transformation?” Second, the interaction with the Knowledge Organizer brought more explanation to answer the first question: “How did the interaction with the
authoring tool affect the knowledge transformation?” Last, the analysis of the artifacts answered the third question: “What are the specific roles of the instructional knowledge?”

**Stimulated recall verbal report**

The stimulated recall verbal report was the main data source of this study. Its purpose was to obtain the participants’ thinking process through their verbal report. During the performance tasks, the participants’ performance was videotaped, and it was used as stimulus to recall the participants’ memory. The videotape was played to show what participants were doing during their tasks. To conduct the stimulated recall verbal report, there were several factors in capturing a more valid and reliable verbal report: 1) timing, 2) prompting, and 3) specifying instruction (Ericsson & Simon, 1993; Gass & Mackey, 2000).

First, timing was very important to minimize the participants’ memory loss. If the participants’ recall was delayed they may not be able to remember what they were thinking during the performance tasks. In addition to this memory loss, delayed recall might cause a more serious problem in analyzing and interpreting the data. According to Gass and Mackey (2000), “as the event becomes more distant in time and memory, there is a greater chance that participants may say what they think the researcher wants them to say or may create a plausible explanation for themselves because the event is less sharply focused in their memories” (p.54). Their suggestion was parallel to the invalidity issue of verbalizing one’s own explanation from the Long Term Memory (Ericsson & Simon, 1993; Russo et al., 1989). To prevent the loss of memory and the generating of plausible explanations, it was suggested that a researcher provided adequate stimulus and multiple sources to facilitate the participants’ recall (Gass & Mackey, 2000). Videotape provided strong stimulus to provoke the participants’ recall.

Second, prompting questions should be provided when participants were not clearly verbalizing or just watching the videotape. However, the prompting questions should not direct the participants’ verbal report. If the prompting questions were too
specific, participants might just react by confirming or denying the questions rather than recalling their thinking process. Therefore, if participants were not clearly verbalizing or if they were murmuring, the prompting questions were like, “Can you tell me again?”, “I did not hear that”, or “Can you speak up for me?” Also, if participants paused longer than fifteen seconds in their verbal reports, then the prompting questions were like “What were you thinking here? or “Can you tell me what you were thinking then?” For the prompting questions, the guideline for me was established and attached in Appendix E.

Last, it was crucial to specify instruction in conducting the stimulated recall verbal report in order to collect a reliable verbal report because participants’ verbal report could be easily affected by what instructions were given before their verbalization. During the Model Initiation and Model Elaboration Stages, it was repeatedly identified that it was important to remind participants how to perform verbal reporting. Participants in the Model Initiation and Elaboration Stages were not always aware of what they were doing (verbal reporting). Appendix E also shows the instruction in conducting the stimulated recall verbal report.

**Self-description**

Participants were asked to report two self-descriptions after each task of organizing concepts and building a concept map. For the self-description, after organizing the concepts using the Knowledge Organizer, a participant was asked to describe why the concepts were grouped on a content slide. Participants could type their explanation into a text box on each content slide. The same questions were asked of participants right after finishing the concept map. The self-descriptions provided additional information to analyze and interpret the data of this study because it directly gave to me participants’ perspective in explaining their cognitive process. In addition, it would be helpful for participants to express what they were considering.
Interview

An interview followed after the stimulated recall verbal report while the interview process was being videotaped. Two types of interviews were conducted for 1) the self-descriptions of the Knowledge Organizer and Concept Map Builder and 2) the cognitive process with contrast questions.

**Interview for the self-descriptions.** In this study there were self-descriptions of the Knowledge Organizer and the Concept Map Builder. The purpose of these two descriptions was to allow participants to describe the reasons for their performance. During the Model Elaboration Stage, there was a self-description only for the Knowledge Organizer because the concept map process was not applied. It was observed from the Model Elaboration Stage that participants could not fully explain the reasons in a written format when they were asked to type the reasons for linking some concepts to a key concept.

There were two potential reasons for such responses in the Model Elaboration Stage. First, there was a lack of clarity in their decision. They had some reasons for their actions, but it would not be easy to explain the reasons in a written format. Second, the self-description of the Knowledge Organizer required a content-intensive explanation because participants had to explain the relationship between the concepts. For these reasons, it would not be easy for participants to explain why they linked certain concepts as a group in a written format. It was anticipated that participants in the Model Theorization Stage would have similar problems for the self-description of the Knowledge Organizer as well as that of the Concept Map Builder. For this reason it was determined that the interview method, as an oral description, should be applied to participants to support their self-description. The interview was conducted with predetermined questionnaires (Appendix F) though participants’ responses were allowed to facilitate a more open-ended format.

**Interview for cognitive process.** During the Model Initiation and Elaboration Stages, when participants reported their cognitive process, their verbal reports, ideally,
verbalized what cognitive processes were happening without reasoning from LTM. However, there were some studies reporting the limitations of using verbal reports when the verbal reporter was unable or unwilling to articulate reasons for the thinking process because of the respondents’ exhaustion or ignorance of an explanation (Pomerantz, 2003; Ramey & Boren, 2000), and then, the exhausted or ignored thinking processes would potentially remain as not-verbalized.

The purpose of the interview about the cognitive process was to encourage the articulation of potentially not-verbalized thinking processes. To meet this purpose, contrast questions, also referred as the flip-flop technique (Strauss & Corbin, 1998), was asked of participants. The purpose of the contrast question was to challenge participants to think about other situations or events and elicit participants’ meanings for events and behaviors (Marshall & Rossman, 1999). Through the response to those questions, the researcher could have a better understanding of an observed behavior (Strauss & Corbin, 1998). It also guided the researcher to discover the dimensions of meaning that respondents employ to distinguish events in their perspective (Spradley, 1979). Specifically, the contrast questions for this study were meant to stimulate participants by asking about different conditions or strategies of knowledge transformation. For instance, if a different performance goal was asked of participants, they might differently organize the concepts. The problem statement in the Knowledge Organizer defined the participants’ target audience as “novices” who did not have prior knowledge of Ausubel’s theory (See Figure 4-5). The contrast question for the different performance goal would be, “If your students were not novice, would the numbers of chunks you used in the Knowledge Organizer be different?”

Two types of contrast questions were used in this interview regarding the cognitive process: 1) directed contrast questions and 2) contrast verification questions. The directed contrast question asked about a known characteristic in a contrast set (Spradley, 1979). Such questions were based on the findings of the Model Elaboration Stage: 1) content knowledge, 2) causal conditions, 3) internal modification of content.
knowledge, 4) external representation by tool regulation, and 5) instructional knowledge (See Appendix F). Some contrast questions that were used in this interview were:

- “If you were not familiar with the concepts, what would be the most difficult things for you to organize?” (For content knowledge)
- “If your students were not novice as described in the problem statement of the Knowledge Organizer, would the number of chunks you made be different?” (For authoring goal of the causal conditions)
- “If you had to use PowerPoint to make the learning material for your students, how it would the material be different from that produced with the Knowledge Organizer?” (For authoring tool of the causal conditions)

The contrast verification question was meant to confirm differences and similarities among a large group of meanings that have been identified through study (Spradley, 1979). For this study the contrast verification question was applied to elicit why participants used different strategies to organize the concepts. During the Model Elaboration Stage, it had been observed that the participants (Bob, Mike, and Jen) applied different strategies to determine the size and sequence of chunks. However, it was not fully investigated why they used the different strategies. For the Model Theorization Stage, the contrast verification questions were used to examine how each participant determines the size and sequence of chunks. Furthermore, the questions were used to verify if similar strategies of determining the size and sequencing the chunks were used with similar reasons from the participants.

Formulating specific contrast verification questions was impossible ahead of time, as the specific questions that must be asked were highly dependent on the respondent and what he or she did -- or more specifically did not --say (Pomerantz, 2003). Some questions that were used in this interview are (See Appendix F):
Why do the sizes of chunks differ? (For the size of chunks if they were grouped into different sizes)

Why did you put this concept in first place instead of second place in the order? (For the sequence of chunks)

**Interaction with the knowledge organizer**

Interaction with the Knowledge Organizer was analyzed to conduct the visual analysis of how participants are interacting with the Knowledge Organizer. Analysis of visual data was important for researchers because it contained valuable non-verbal dimensions of behavior and communication, which speech or discourse could never include (Rose, 2000). In this study, non-verbal features were defined as the interaction between participants and the computer applications. From the Human Computer Interaction (HCI) perspective, it was important how computers were used and the ways interaction was facilitated between people and computers (Eysenck, 1990). In general the disciplines of HCI were “studying the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Hewett et al., 1992). Although this study did not directly focus on the issues of HCI, the analysis of interactions with the application would support the interpretation of how participants transform their knowledge through the use of the Knowledge Organizer.

When participants organized the concepts through the Knowledge Organizer, they had to operate the applications to accomplish the performance tasks. Although participants were assumed to have prior knowledge of the given concepts, they had to visually navigate the screen of the applications to locate and select information for the performance tasks. This visual navigation, also known as visual search, was a search process to find information (Deshe & VanLaar, 1999). Visual search of a computer screen was often followed by manual selection with a mouse (Hornof & Kieras, 1997). Particularly mouse movements were very important for this study because the
Knowledge Organizer was based only on mouse events to operate it. Identifying mouse activities was thus necessary for this study to code and analyze the interaction with the applications. Several types of mouse activity were available for the Knowledge Organizer: move, click, drag-and-drop, and idle.

The unit of analysis for the interaction were limited to three steps of the Knowledge Organizer: 1) select key concepts, 2) sequence the selected key concepts, and 3) link other concepts to key concept (See Figure 4-4, 4-5, and 4-6). Analyzing the interaction with the Knowledge Organizer revealed how authoring functions were related to the cognitive processes of knowledge transformation.

Artifacts

There were two artifacts for each participant, which were produced from the Knowledge Organizer and Concept Map Builder. Although both of the artifacts represented participants’ cognitive product either to organize the concepts or to externalize participants’ knowledge structure in the concepts, the nature of the artifacts were different. First, the purpose of creating the artifacts was different. The artifact of the Knowledge Organizer was based on a specific goal to create a document. For this study, it was to organize the given concepts to develop a learning material for graduate students. However, the artifact of the Concept Map Builder was to externalize the structural representation of a participant’s knowledge in the given concepts without an organizing goal. Second, participants had to follow an enforced structure to organize the concepts using the Knowledge Organizer. For instance, the Knowledge Organizer had a top-down way of organizing the concepts. However, there was no specific structure to externalize their knowledge structure in the Concept Map Builder. For these reasons, as seen in the Model Initiation Stage, the representational structures of the artifacts by the Knowledge Organizer and Concept Map Builder might be different.

In the Model Theorization Stage, both of the artifacts were compared to examine how they were different. The comparison was focused on the structural representations of
concepts in the artifacts. Particularly the differences between the two artifacts articulated the role of instructional knowledge, which had been identified in the Model Elaboration Stage. From the result of the Model Elaboration Stage it was concluded that instructional knowledge mediated in determining the chunk size and sequence of the chunks to organize the concepts. This mediation occurred to achieve the given goal of organizing the concepts. However, it was assumed that the Concept Map Builder in the Model Theorization Stage did not require instructional knowledge because there was no specific goal to meet to make a concept map. By comparing the artifact of the Concept Map Builder, it thus showed how the absence or presence of activating instructional knowledge affects knowledge transformation through the authoring process.

Data Preparation

The four data sources were converted into three different data formats for the data analysis. First, the stimulated recall verbal report and interview were transcribed and typed into verbatim transcripts. Second, the videotape record was converted into a digitalized video file format. Last, the artifacts were converted into graphic images.

Verbatim transcript

The original data formats of the stimulated recall verbal report and interview were videotapes of the verbal reporting and interviewing. They were transcribed and typed into verbatim transcripts in Korean from the videotapes. All transcriptions were converted into an electronic format. For the transcribing process I transcribed an initial transcript, and then one Korean graduate student participated to verify if the two data sources were accurately documented.
Interaction with the knowledge organizer

For the analysis of the interaction with the Knowledge Organizer, the mouse events were defined in Table 4-2. The videotape recording the interaction with the Knowledge Organizer was converted into an electronic format. Then, participants’ mouse movements were observed according to the definition of mouse events, but the duration time for each mouse event was not measured because the performance task did not have a time constraint to accomplish it.

Artifacts

Both of the artifacts by the Knowledge Organizer and Concept Map Builder were converted into a graphic format. In the Knowledge Organizer, the sequence of the organized concepts was important. Thus, the converted graphic represented the sequence and order of the concepts. The final screen of the Concept Map Builder were captured to convert the concept map into a graphic format.

<table>
<thead>
<tr>
<th>Mouse Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move</td>
<td>Move a mouse point to a target object in the screen to conduct a certain event</td>
</tr>
<tr>
<td>Click</td>
<td>Click a mouse button to activate a target object in the screen</td>
</tr>
<tr>
<td>Drag and Drop</td>
<td>Drag a target object with pressing a mouse button and than release the button to drop the target object in a designated area</td>
</tr>
<tr>
<td>Idle</td>
<td>Move a mouse point without a specific purpose</td>
</tr>
</tbody>
</table>
Data Analysis

As described in chapter three, this study applied grounded theory as an analysis method. Specifically, this study employed two main techniques of grounded theory: 1) iterative data analysis process and 2) constant comparative analysis. Based on these techniques, this study established three stages for the model saturation process: Model Initiation, Model Elaboration, and Model Theorization Stages. The main purpose of applying the iterative process was to enable me to have a “sensitizing framework” to immerse in the research context. Through the results from the Model Initiation Stage and the Model Elaboration Stage of the iterative model saturation process, five cognitive components had been identified as illustrated in Figure 3-5: 1) content knowledge, 2) causal conditions, 3) internal modification, 4) external representation by tool regulation, and 5) instructional knowledge.

Based on the five components from the Model Initiation and Model Elaboration Stages, the Model Theorization Stage took analysis through microscopic examination of data. The microscopic analysis was the detailed, line-by-line analysis (Strauss & Corbin, 1998). Particularly, for this study, there were two aspects of the microscopic analysis: 1) globalization and 2) localization of the data analysis. First, globalization of the data analysis meant that the microanalysis of the Model Theorization Stage included the results of the Model Initiation and Model Elaboration Stages to increase the power of interpretation. For instance, the Model Initiation Stage examined a single case, but it did not scrutinize multiple numbers of participants. The Model Elaboration Stage used multiple participants, but there was no analysis of their concept map building process, which was analyzed in the Model Initiation Stage. Including all aspects of the data collection increased the researcher’s interpretation and understanding at the global level. Second, the localization of the data analysis was related to specifying detailed data...
collection to answer the three questions from the On-going Model: 1) “How did the interaction with the authoring tool affect the knowledge transformation?”, 2) “What were the cognitive strategies being used in the knowledge transformation?”, and 3) “What were the specific roles of the Instructional Knowledge?” The integration of the Model Initiation and Elaboration Stages had established the five cognitive components. The cognitive components played a role in providing me specific cognitive dimensions to be analyzed for building a cognitive model of the knowledge transformation. In other words, the components guided the direction of analysis in the Model Theorizing Stage.

**Research tool**

This study used the computer software, Atlas/ti, for the analysis of the data. Using the computer software for the qualitative research enabled me to more systematically analyze the data (Kent, 2001). There were two considerations to select Atlas/ti as a research tool for this study. First, it was necessary to display different types of media and data sources all at once in a screen so that the research was able to cross over them. The data sources of this study was converted into three different types of media format: 1) verbatim transcript, 2) interaction with the Knowledge Organizer, and 3) artifacts. The computer software should have capabilities to load and display these types of formats.

Second, the computer software should be more flexible to build a data structure because of the dynamic nature of cognition. This study was dealing with higher-order thinking processes, which were not linear in their flow but were very dynamic. In addition the research setting, including the performance goal and tasks, were artificial and not based on long-term experiences for the participants. These dynamic and artificial characteristics of the research setting were requiring high flexibility to structure the data. For these two considerations, Atlas/ti was selected.

**Data coding**
This study followed three phases of the coding process (Creswell, 1998; Strauss & Corbin, 1998): 1) open coding, 2) axial coding, and 3) selective coding. First, open coding was meant to help a researcher carry out the steps of theory building: conceptualizing, defining categories, and developing categories. Although this study already had established cognitive components as the On-going Model, the open coding process still helped me elaborate the concepts and categories. During the Model Theorization Stage, several new concepts were identified, and the new concepts reflected participants’ concerns of how to externalize their prior knowledge into an artifact for students. For instance, participants expressed about students’ knowledge level, length of instruction, amount of concepts to teach, and so on. Each of these new concepts and concerns was regarded as open codes.

For the next phase, the axial coding was conducted. The purpose of the axial coding was to relate the categories to their sub-categories and link the categories at the level of properties and dimensions. The identified open codes were then categorized into a more global concept. For instance, the concepts of students’ knowledge level, length of instruction, amount of concepts to teach were categorized into a goal configuration. Then, finally the goal configuration was labeled as the authoring goal. In this step, I was able to elaborate the five cognitive components based on the identified concepts/categories from the open coding. Specifically, the axial coding enabled me to answer the three questions raised from the On-going Model.

As a final phase, the selective coding was conducted. While the open coding was meant to generate concepts or categories and the axial coding was meant to link the emerged concepts or categories during the open coding, the selective coding was intended to integrate them as a theory. As a theory, the result of the selective coding satisfied three criteria (Strauss & Corbin, 1998). First, the set of concepts or categories represented not only an individual’s behavior but, rather, behaviors of all of the participants reduced into highly conceptual terms. Second, the findings were presented as architecture with interrelated concepts, not just a listing of terms. Third, the theory could
be stated in the narrative manner of interwoven concepts rather than explicit hypotheses or propositions.

**Translation of reporting**

Since the primary language for collecting and analyzing the data was Korean, it was necessary to translate some significant data into English for the report. All data analysis was conducted without translating the primary language as collected. Once the significant data were selected from verbal reports, interview, self-description, or artifacts, I translated them as a preliminary translation document. Then another Korean interpreters reviewed the preliminary translation sentence-by-sentence. Only when both the researcher and another Korean of the interpreters agreed that a sentence was translated well enough to deliver the original meaning in English, the translation then was reviewed by a native English speaker.
CHAPTER 5  
RESULTS

Descriptions

Participants

Six participants, two males and four females, completed the performance tasks for the Model Theorization Stage. All of them have enrolled in a graduate program of instructional systems at a southeast public university. Five participants were doctoral students, and one was a master student. Their pseudonyms were John, Sally, Helen, Ryan, Susan, and Jessica.

John is a 3rd year doctoral student, and he earned a master’s degree of instructional technology in Korea. He is a graduate assistant of an institute of the southeast university. John has participated in several large-scale projects of instructional design and development. He took a course with the textbook, Psychology of Learning for Instruction (Driscoll, 2000), which was used for the subject matter of this study, in the fall semester of 2001.

Sally is a 2nd year master student, and she earned her undergraduate degree in English while in Korea. Also, she was an English teacher for middle students in Korea for 5 years. Sally joined an instructional development project as a graduate assistant. She took the course that deals with the subject matter of this study in the fall semester of 2003.
Helen is a 1st year doctoral student, and she earned her master’s degree of educational psychology in Korea. She finished her coursework for her doctoral degree in educational psychology in Korea; but she entered a doctoral program of instructional systems at the southeast university. Helen has 4 years teaching experience at a college level in Korea. She taught classes for educational psychology and learning theories. She took the course dealing with the subject matter of this study in the fall semester of 2003.

Ryan is a 2nd year doctoral student. He earned his master’s degree of instructional systems in the southeast university. After his master degree, he worked for a training department of a large-scale company for one and a half years. During his work, Ryan designed and developed training materials. He has been working as a graduate assistant in an institute of the southeast university. Ryan took the course dealing with the subject matter of this study in the fall semester of 2000.

Susan is a 2nd year doctoral student. She earned her master degree in instructional systems in 2002 from the southeast university. She has been working as a graduate assistant in the same university for three years. Susan participated in several large-scale projects for designing and developing training materials. She took the course dealing with the subject matter of this study in the fall semester of 2001.

Jessica is a 3rd year doctoral student. She earned her master degree in instructional technology in a northeast public university. After graduation, she worked in a multimedia development company for 5 years. Jessica has been working as a graduate student. She took the course dealing with the subject matter of this study in the fall semester of 2001.

**Participation time**

The average participation time was approximately 120 minutes. Participants spent on average 40 minutes to perform the task with the Knowledge Organizer and Concept Map Builder. Then, they participated in the stimulated recall verbal report for an average of 45 minutes each. Also, each interview with participants took approximately 25 minutes.
Familiarity and understanding of the concepts

At the beginning of the Model Theorization Stage, participants were given an instrument to measure their prior knowledge of the given concepts. Specifically, this instrument was designed to measure the familiarity with and understanding of the given concepts with a 5-point Liker scale (See a third step of the procedure in Figure 4-12). The average scores of the instrument were 3.96 and 4.28 with the standard deviations of .95 and .91 for familiarity and understanding respectively. For the familiarity of the given 13 concepts, participants rated 33.3%, 37.2%, 23.1%, 5.1%, and 1.3% of the concepts as “very well familiar”, “familiar”, “neutral”, “not familiar”, and “not at all familiar” respectively. Only one participant rated one concept as “not at all”, and three participants rated four concepts as “not familiar”. The positive rates of familiarity of the 13 concepts were summed up to 70.5%, while the negative rates of “not familiar” and “not at all” were 6.4%.

Table 5-1. Descriptive Statistics of the Scores of Familiarity and Understanding of the Concepts

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity Mean (SD)</th>
<th>Understanding Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>4.14 (0.90)</td>
<td>4.43 (0.79)</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>4.14 (0.69)</td>
<td>4.29 (0.49)</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>4.29 (0.76)</td>
<td>4.29 (0.76)</td>
</tr>
<tr>
<td>Discovery Learning:</td>
<td>4.43 (0.79)</td>
<td>4.29 (0.49)</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>3.14 (0.69)</td>
<td>4.00 (1.15)</td>
</tr>
<tr>
<td>Learning Material</td>
<td>4.00 (0.82)</td>
<td>4.29 (0.76)</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>4.43 (0.79)</td>
<td>4.29 (1.11)</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>3.86 (1.07)</td>
<td>4.00 (1.15)</td>
</tr>
<tr>
<td>Readiness</td>
<td>4.43 (0.79)</td>
<td>4.71 (0.76)</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>3.29 (1.11)</td>
<td>4.00 (1.15)</td>
</tr>
<tr>
<td>Retention</td>
<td>4.43 (0.53)</td>
<td>4.71 (0.49)</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>3.29 (1.70)</td>
<td>3.57 (1.62)</td>
</tr>
<tr>
<td>Understanding</td>
<td>4.00 (0.82)</td>
<td>4.43 (0.79)</td>
</tr>
</tbody>
</table>
For the understanding of the given concepts, participants rated 50.0% 35.9%, 7.7%, 5.1%, and 1.3% of the concepts as “very well understood”, “understood”, “neutral”, “not understood”, and “not at all understood” respectively. While the positive rates of the understanding of the 13 concepts were summed up to 85.9% for “very well understood” and “understood”, the negative rates of the understanding of the concepts were 6.4%. The increased positive rates from the familiarity to the understanding of the 13 concepts indicated that reading the concepts refreshed participants’ prior knowledge about Ausubel’s concepts. Also, it was assumed that participants had a sufficient amount of prior knowledge of the given concepts. Table 5-1 shows the average scores of the familiarity and understanding for each concept rated by participants.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Discovery Learning:</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Learning Material</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Readiness</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Retention</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Understanding</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

| Mean                                            | 4.00        | 4.38          |
**John.** John’s average scores for familiarity and understanding of the concepts were 4.0 and 4.38 respectively. For the familiarity scores, he rated nine concepts as either “very well familiar” or “familiar”, and the ratios of his positive rate for the familiar scores were 38.5% and 30.8% for “very well familiar” and “familiar” respectively. John rated only one concept as “not familiar”. For the understanding scores, he rated all of the concepts as either “very well understood” or “understood” with the ratios of 38.5% and 61.5% respectively. Table 5-2 shows John’s rates for the familiarity and understanding scores of the 13 concepts.

**Sally.** Sally’s average scores for the familiarity and understanding of the concepts were 4.69 and 4.92 respectively. For the familiarity scores, she rated all of the concepts as either “very well familiar” or “familiar”, and the ratios of her rates were 69.2% and 30.8% respectively. Sally also rated all of the concepts as either “very well understood” or “understood” for the understanding scores with the ratios of 92.3% and 7.7%. Table 5-3 shows Sally’s rates for the familiarity and understanding scores of the 13 concepts.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Discovery Learning:</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Learning Material</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Readiness</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Retention</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Understanding</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>4.69</strong></td>
<td><strong>4.92</strong></td>
</tr>
</tbody>
</table>

Table 5-3. Sally’s Rates for the Familiarity and Understanding Scores of the Concepts
Helen. Helen’s average scores for familiarity and understanding of the concepts were 4.38 and 4.69 respectively. She rated 10 concepts as either “very well familiar” or “familiar” for the familiarity of concepts. The rates of “very well familiar” and “familiar” were 69.2% and 7.7%; thus, the ratios of positive rates of the familiarity were summed as 76.9%. For the understanding, Helen rated 12 concepts as either “very well understood” or “understood”, and the rates were 76.9% and 15.4% respectively. Table 5-4 shows Helen’s rates for the familiarity and understanding scores of the 13 concepts.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Discovery Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Learning Material</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Readiness</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Retention</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Understanding</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>4.38</strong></td>
<td><strong>4.69</strong></td>
</tr>
</tbody>
</table>

Ryan. Ryan’s average scores for familiarity and understanding of the concepts were 3.92 and 4.54 respectively. For familiarity, he rated 10 concepts as either “very well well
familiar” or “familiar” with the ratios of 15.4% and 61.5% respectively. His positive rates were 76.9% for familiarity. Ryan rated all of the concepts as either “very well understood” or “understood” for the understanding scales. His ratios for “very well understood” and “understood” were 53.8% and 46.2% respectively. Table 5-5 shows Helen’s rates for the familiarity and understanding scores of the 13 concepts.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Discovery Learning</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Learning Material</td>
<td>3</td>
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</tr>
<tr>
<td>Meaningful Learning</td>
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<td>4</td>
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<tr>
<td>Prerequisites of Meaningful Learning</td>
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</tr>
<tr>
<td>Readiness</td>
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<td>5</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Retention</td>
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<td>5</td>
</tr>
<tr>
<td>Rote Learning</td>
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<td>5</td>
</tr>
<tr>
<td>Understanding</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
<td>3.92</td>
<td>4.54</td>
</tr>
</tbody>
</table>

**Table 5-5. Ryan’s Rates for the Familiarity and Understanding Scores of the Concepts**

Susan. Susan’s average scores for the familiarity and understanding of the concepts were 3.16 and 2.77 respectively. She rated 5 concepts as either “very well familiar” or “familiar” for the familiarity of concepts. The ratios of “very well familiar” and “familiar” were 7.7% and 30.8%; thus, the positive rates of the familiarity were summed up to 38.5%. For the understanding, Susan rated only 4 concepts as “understood” with the ratio of 23.1%. Unlike other participants she evaluated her
understanding at lower level. Susan rated 5 concepts as either “not understood” or “not at all understood” with ratios of 30.8% and 7.7% respectively. Table 5-6 shows Susan’s rates for the familiarity and understanding scores of the 13 concepts.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Discovery Learning:</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Learning Material</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Readiness</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Retention</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Understanding</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 5-6.** Susan’s Rates for the Familiarity and Understanding Scores of the Concepts

**Jessica.** Jessica’s average scores for the familiarity and understanding of the concepts were 3.62 and 4.38 respectively. For familiarity, she rated only 4 concepts as “familiar” with the ratio of 61.5%, but she rated the rest of concepts as “neutral” with the ratio of 38.5%. Jessica rated all of the concepts as either “very well understood” or “understood” for the understanding scales. Her ratios for “very well understood” and “understood” were 38.5% and 61.5% respectively. Table 5-7 shows Jessica’s rates for the familiarity and understanding scores of the 13 concepts.
Table 5-7. Jessica’s Rates for the Familiarity and Understanding Scores of the Concepts

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Familiarity</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Discovery Learning:</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Learning Material</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Readiness</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Reception Learning</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Retention</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Rote Learning</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Understanding</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>3.62</strong></td>
<td><strong>4.38</strong></td>
</tr>
</tbody>
</table>

Knowledge Structures

Content structure of the knowledge organizer

Participants created various content structures using the Knowledge Organizer. Most of participants selected three chunks as key concepts. Only Susan selected two concepts as key concepts for her content structure using the Knowledge Organizer. Although all of the participants were informed that it was not necessary to select and organize all of the given 13 concepts through the Knowledge Organizer, only John and
Helen omitted some concepts from the content structures they created when using the Knowledge Organizer. The other participants used all of the given concepts.

The following Figures 5-1, 5-2, 5-3, 5-4, 5-5, and 5-6 show the content structures created by the participants when using the Knowledge Organizer. In the figures, each concept box has two numbers in a parenthesis. The numbers indicate the familiarity and understanding scores participants rated respectively. Participants were asked to create an order for the sequence of the key concepts; thus the key concepts were sequenced as determined by participants. The participants did get to determine which key concept each sub-concept belonged to, although they did not get to determine a sequence amongst the sub-concepts within each chunk. Thus, the sub-concepts belonging to each key concept were displayed in an alphabetical order in the figures. Each key concept together with its related sub-concepts was referred to as a chapter or a chunk. Thus, the terms chapter and chunk were used interchangeably in the following sections.

**John.** John selected as keys the three concepts of “prerequisites of meaningful learning”, “assimilation theory”, and “discovery learning”, as illustrated in Figure 5-1. The familiarity scores of the key concepts were 5, 4, and 4 respectively. The understanding scores of the key concepts were 4, 4, and 4 respective. John assigned three sub-concepts to each key concept. In using the Knowledge Organizer, he did not select “reception learning” from the 13 concepts for his content structure. His familiarity and understanding scores for the “reception learning” concept were 2 and 4.

**Sally.** Sally used all of the given 13 concepts to build the content structure and selected “cognitive structure” and “meaningful learning” as key concepts. Sally assigned 5 sub-concepts to “cognitive structure” and 6 sub-concepts to “meaningful learning”. Figure 5-2 shows the content structure Sally created using the Knowledge Organizer.
Helen. Helen used 9 concepts out of the 13 concepts. That is, she omitted 4 concepts because she thought that they were not useful for her instructional plan. The omitted concepts were “discovery learning”, “reception learning”, “retention”, and “rote learning”. The familiarity scores of the omitted concepts were 5, 3, 5, and 2 respectively. The understanding scores of the omitted concepts were 5, 4, 5, and 3 respectively. Helen selected the 3 concepts of “cognitive structure”, “meaningful learning”, and “learning material” for the chapters. She assigned 3 sub-concepts to both “cognitive structure” and “meaningful learning”. Interestingly, Helen did not include any sub-concepts in the last chapter. Figure 5-3 shows the content structure Helen created using the Knowledge Organizer.
Cognitive Structure (5/5)  
  Anchoring Ideas (5/5)  
  Assimilation Theory (4/4)  
  Influence of Knowledge Structure (4/5)  
  Retention (5/5)  
  Understanding (4/5)

Meaningful Learning (5/5)  
  Discovery Learning (5/5)  
  Learning Material (5/5)  
  Prerequisites of Meaningful Learning (4/5)  
  Readiness (5/5)  
  Reception Learning (5/5)  
  Rote Learning (5/5)

Figure 5-2. Sally’s Content Structure of the Knowledge Organizer

Cognitive Structure (5/5)  
  Anchoring Ideas (5/5)  
  Influence of Knowledge Structure (3/4)  
  Readiness (5/5)

Meaningful Learning (5/5)  
  Assimilation Theory (5/5)  
  Prerequisites of Meaningful Learning (5/5)  
  Understanding (5/5)

Discovery Learning (4/5)

Figure 5-3. Helen’s Content Structure of the Knowledge Organizer
**Ryan.** Ryan used all of the given concepts in creating his content structure. He selected 3 concepts for the chapters. The key concepts were “cognitive structure”, “assimilation theory”, and “meaningful learning” as illustrated in Figure 5-4. The familiarity scores of the key concepts were 4, 4, and 4 respectively. The understanding scores of the key concepts were 4, 4, and 4 respectively. To “cognitive structure” he assigned the 3 sub-concepts of “anchoring ideas”, “influence of knowledge structure”, and “readiness”. To “assimilation theory” he assigned the 3 sub-concepts of “discovery learning”, “reception learning”, and “rote learning”. In the “meaningful learning” chapter he included the 4 sub-concepts of “learning material”, “prerequisites of meaningful learning”, “retention”, and “understanding”.

![Figure 5-4. Ryan’s Content Structure of the Knowledge Organizer](image-url)
Susan. Susan also used all of the given 13 concepts. She selected 3 concepts as key concepts. The key concepts were “cognitive structure”, “meaningful learning”, and “reception learning”. The familiarity scores of the key concepts were 4, 3, and 2 respectively. The understanding scores of the key concepts were 3, 2, and 2 respectively. To “cognitive structure” she assigned the 5 sub-concepts of “anchoring ideas”, “assimilation theory”, “discovery learning”, “influence of knowledge structure”, and “readiness”. To “meaningful learning” she assigned only 2 sub-concepts, “learning material” and “prerequisites of meaningful learning”. In the “reception learning” chapter she included the 3 sub-concepts of “retention”, “rote learning”, and “understanding”. Figure 5-5 shows the content structure Susan created using the Knowledge Organizer.
Jessica. Jessica used all of the 13 concepts to organize her instructional material. She selected the 3 concepts of “cognitive structure”, “anchoring ideas”, and “assimilation theory” as key concepts. The familiarity scores of the key concepts were 3, 3, and 3. The understanding scores of the key concepts were 4, 4, and 4. She assigned 2 sub-concepts to the “cognitive structure” chapter and 4 sub-concepts to the chapter “anchoring ideas”. Lastly, in the “assimilation theory” chapter she included 4 sub-concepts. Figure 5-6 shows the content structure Jessica created using the Knowledge Organizer.

```
  Cognitive Structure (3/4) --- Influence of Knowledge Structure (3/5)
                    |                                    Retention (4/5)
  Anchoring Ideas (3/4) --- Learning Material (4/4)
                    |                                    Meaningful Learning (4/4)
                    |                                    Prerequisites of Meaningful Learning (4/4)
                    |                                    Readiness (4/5)
  Assimilation Theory (3/4) --- Discovery Learning (4/4)
                      |                                    Reception Learning (4/5)
                      |                                    Rote Learning (3/4)
                      |                                    Understanding (4/5)
```

Figure 5-6. Jessica’s Content Structure of the Knowledge Organizer

Summary. The content structures participants developed through use of the Knowledge Organizer revealed a couple of patterns of organizing the concepts. First,
there were most-preferred concepts grouped into a first chunk (chapter). Participants mostly selected the concepts of “cognitive structure”, “influence of knowledge structure”, “anchoring ideas”, and “readiness” for a first chunk. The frequencies of selecting these concepts for a first chunk were 6, 5, 4, and 4 respectively. Particularly “anchoring ideas”, “cognitive structure”, and “influence of knowledge structure” were selected only for a first chunk. In other words, those concepts were not selected for any other chunks, but for a first chunk only. However, unlike these concepts, the concepts of “learning material”, “meaningful learning”, “reception learning”, and “rote learning” were never selected for a first chunk.

Table 5-8. Frequencies and Ratios of Concepts Selected for First and Last Chunk.

<table>
<thead>
<tr>
<th>Concept Title</th>
<th>Frequencies and Ratios of Used</th>
<th>In a First Chunk</th>
<th>In a Last Chunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchoring Ideas</td>
<td>4 (14.81%) *</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Assimilation Theory</td>
<td>2 (7.41%)</td>
<td>1 (3.85%)</td>
<td></td>
</tr>
<tr>
<td>Cognitive Structure</td>
<td>6 (22.22%) *</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Discovery Learning</td>
<td>1 (3.70%)</td>
<td>3 (11.54%) *</td>
<td></td>
</tr>
<tr>
<td>Influence of Knowledge Structure</td>
<td>5 (18.52%) *</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Learning Material</td>
<td>0 (0%)</td>
<td>4 (15.38%) *</td>
<td></td>
</tr>
<tr>
<td>Meaningful Learning</td>
<td>0 (0%)</td>
<td>3 (11.54%) *</td>
<td></td>
</tr>
<tr>
<td>Prerequisites of Meaningful Learning</td>
<td>1 (3.70%)</td>
<td>2 (7.69%)</td>
<td></td>
</tr>
<tr>
<td>Readiness</td>
<td>4 (14.81%) *</td>
<td>1 (3.85%)</td>
<td></td>
</tr>
<tr>
<td>Reception Learning</td>
<td>0 (0%)</td>
<td>3 (11.54%) *</td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>2 (7.41%)</td>
<td>3 (11.54%) *</td>
<td></td>
</tr>
<tr>
<td>Rote Learning</td>
<td>0 (0%)</td>
<td>3 (11.54%) *</td>
<td></td>
</tr>
<tr>
<td>Understanding</td>
<td>2 (7.41%)</td>
<td>3 (11.54%) *</td>
<td></td>
</tr>
</tbody>
</table>

Second, there were some preferred concepts to be selected in a last chunk. The most frequently selected concept for a last chunk was the concept “learning material”, and it was selected 4 times for a last chunk. Similarly, the concepts of “discovery
learning”, “meaningful learning”, “reception learning”, “retention”, “rote learning”, and understanding were most often selected in a last chunk. In particular, “learning material”, “meaningful learning”, “reception learning”, and “rote learning” were selected only for a last chunk but never for a first chunk. Table 5-8 shows the frequencies and ratios of concepts used in a first and last chunk.

Third, there were most-preferred concepts selected as key concepts for chapters. The concept of “cognitive structure” was the one most frequently selected as a key concept. Specifically, this concept was selected as a key concept for the first chapter of the content structure. Table 5-9 shows what concepts were selected as key concepts for chapters of the content structure that participants created by using the Knowledge Organizer. Since all participants made a three-chunk structure except for Sally, Table 5-9 was presented to compare what concepts were selected as a chapter for each chunk across the three chapters. As seen in Table 5-9, interestingly, most participants wanted to start with the concept of cognitive structure as their first chapter. Also, the concept of meaningful learning was mostly selected for either a second or third chunk.

<table>
<thead>
<tr>
<th>Participant</th>
<th>First Chunk</th>
<th>Middle Chunk</th>
<th>Last Chunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>Prerequisite of</td>
<td>Assimilation Theory</td>
<td>Discovery Learning</td>
</tr>
<tr>
<td></td>
<td>Meaningful Learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sally</td>
<td>Cognitive Structure</td>
<td>-</td>
<td>Meaningful Learning</td>
</tr>
<tr>
<td>Helen</td>
<td>Cognitive Structure</td>
<td>Meaningful Learning</td>
<td>Learning Material</td>
</tr>
<tr>
<td>Ryan</td>
<td>Cognitive Structure</td>
<td>Assimilation Theory</td>
<td>Meaningful Learning</td>
</tr>
<tr>
<td>Susan</td>
<td>Cognitive Structure</td>
<td>Meaningful Learning</td>
<td>Reception Learning</td>
</tr>
<tr>
<td>Jessica</td>
<td>Cognitive Structure</td>
<td>Anchoring Ideas</td>
<td>Assimilation Theory</td>
</tr>
</tbody>
</table>

Table 5-9. Key Concepts for Each Chunk of the Content Structure of Knowledge Organizer
Last, it was identified that the concepts with lower scores of familiarity and understanding could be used as a key concept. In John’s case, he used the concepts of “assimilation theory” and “discovery learning” as key concepts for a second and third chapter respectively. Yet, the scores of familiarity and understanding of these two concepts were not higher than those of their sub-concepts that were grouped under each key concept (See Figure 5-1). Similarly, Susan selected the concepts of “meaningful learning” and “reception learning” as key concepts for her second and third chunks respectively. However, the scores of familiarity and understanding of the concepts were on average lower than the scores for the chunks’ sub-concepts (See Figure 5-5). In addition, all of the key concepts used in Jessica’s case had on average lower scores than her scores for the sub-concepts she included in the chunks. For instance, the scores for familiarity and understanding of all key concepts for each chunk were 3 and 4 respectively. However, these scores were her lowest scores for all 13 concepts (See Figure 5-6). This finding indicates that high scores of familiarity and understanding of a concept may not be important factors in the selection of a key concept.

**Structures of concept map**

After completing the performance task using the Knowledge Organizer, participants were asked to build their own concept map with the given 13 concepts using the Concept Map Builder. While participants were allowed to omit any concepts in organizing the concepts with the Knowledge Organizer, they had to use all of the given concepts to build their own concept map.

**John.** Figure 5-7 shows John’s concept map. He built the concept map in a very tree like and hierarchical way. The concept of “assimilation theory” was placed at the top of this tree structure. The other concepts were placed under the highest concept depending on the relationship with other higher concepts. While some concepts were
individually placed under “assimilation theory”, several other concepts were grouped. For instance, the concepts of “discovery learning”, “rote learning”, “retention”, and “learning material” were combined as a group. The concepts of “prerequisites of meaningful learning”, “readiness”, “cognitive structure”, and “understanding” were also grouped. These two groups were identical to the chunks of the content structure John created using the Knowledge Organizer. In comparing John’s content structure with his concept map, the concept of “assimilation theory” was used as a key concept for a second chunk in his content structure; however, John selected “assimilation theory” as the core concept of his concept map.

Figure 5-7. Screen Capture of John’s Concept Map
While building the concept map, John was very concerned about similarities between concepts and clarifying the relationship between concepts.

“It took a long time to differentiate subtle meanings between concepts because there were similar meanings. I wanted to make a clear hierarchical structure indicating what concepts should be either higher or subordinate.” [From stimulated recall verbal reporting regarding the concept mapping]

In addition, it was observed that the structural relationship of the concepts would be more important than the individual relationships of a concept for organizing a knowledge structure. In John’s case, he did not use the concept of “reception learning” in his authoring process with the Knowledge Organizer. However, when he had to build a concept map, he had to use all concepts. Then, John positioned the concept of “reception learning” under the concept of “assimilation theory”. From John’s case, it was identified that the structural relationship would have an effect on transforming knowledge.

“I did not select the concept (reception learning) in the authoring process because I thought that it did not need to be included in a chapter though the concept had some relationship with the other concepts. I mean the concept could have relationship with the other concepts; however, it did not mean the concept had to be included in a chapter. That is the reason of why I did not include reception learning in the Knowledge Organizer. However, for the concept map I had to use all of the concepts. Then, I was worried about where would be an appropriate place for the concept.” [From open-ended interview]
John understood an individual relationship of the “reception learning” concept, but he did not select the concept for the content structure because “reception learning” did not fit into the interrelationships of the concepts. However, when he had to make a concept map, he had to use all of concepts.

**Sally.** Figure 5-8 shows Sally’s concept map. Similar to her content structure when using the Knowledge Organizer, she made two groups, and the groups represented the chunks she made with the Knowledge Organizer. The first group consisted of six sub-concepts including “prerequisites of meaningful learning”, “meaningful learning”, “rote learning”, “reception learning”, “discovery learning”, and “understanding”. This group was positioned in the upper portion of Figure 5-8. The second group along with the rest of concepts was positioned in the lower portion of Figure 5-8.

Although the Knowledge Organizer did not have a function to sequence sub-concepts, Sally made sequential links within the groups. For the first group, the core concept of this group was “meaningful learning”. The concept of “prerequisite of meaningful learning” was positioned above of “meaningful learning” because the concept should be a prerequisite of the core concept, “meaningful learning”. Then, the rest of concepts of this group were positioned after the core concept as sub-concepts to support the core concept. Similar sequential links were made for the second group in the same way. For the second group, “cognitive structure” was regarded as a core concept. Then “influence of knowledge structure” was positioned as a prerequisite concept of the core concept, “cognitive structure”. The concepts of “learning material” and “readiness” were positioned as background knowledge for “cognitive structure”. The rest of the concepts were linked and placed after “cognitive structure” as supportive concepts. The relationship between the two groups was not clearly depicted in Sally’s concept map nor was it addressed during the interview with her. According to Sally, she just wanted to make two separate groups corresponding to the two chapters she made for the content structure while using the Knowledge Organizer.
It was important to Sally to arrange the concepts according to the sequence. According to her:

“*I put the prerequisites of meaningful learning first because it should be in advance of the meaningful learning. The concept of prerequisites of meaningful learning was a prerequisite for meaningful learning. I did the same thing for influence of knowledge structure. This concept should be placed above cognitive structure because the concept (influence of knowledge structure) was a prerequisite of cognitive structure.*”  

*From stimulated verbal reporting regarding the concept mapping*
(Question: “Were you concerned about the sequence of the concepts when you were building the concept map as well as when authoring using the Knowledge Organizer?”) “Yes! I wanted to arrange the concepts in the concept map sequentially as I did in authoring with the Knowledge Organizer.” [From open-ended interview]

Sally’s concern for arranging the concepts sequentially seemed to indicate that she wanted to represent her current mental structure that had been modified during the authoring process. Although she was aware that it was not necessary to make the same structure between the content structure and concept map, she wanted to make the concept map the same as the content structure.

**Helen.** Similar to Sally, Helen wanted to make her concept map corresponding to her content structure of the Knowledge Organizer. Figure 5-9 shows her concept map. The characteristics of Helen’s concept map were exactly the same as Sally’s. First, she built the concept map identical to the content structure she created using the Knowledge Organizer. As she developed a three-chapter structure, Helen placed the same key concepts in the middle of the concept map: “cognitive structure”, “meaningful learning”, and “learning material”.

Second, her concept map was arranged in a linear way by placing “cognitive structure” first in the left side of the concept map. Then, she placed “meaningful learning” as the next core concept. The concept of “learning material” was placed as the last concept in a linear way from the cognitive structure.

Third, Helen placed two concepts as prerequisites for “cognitive structure” and “meaningful learning” in the upper portion of the map. As shown in Figure 5-9, the concepts of “influence of knowledge structure” and “prerequisites of meaningful learning” were placed as prerequisite concepts for “cognitive structure” and “meaningful learning” respectively. Then, the rest of concepts were positioned under the key concepts.
Figure 5-9. Screen Capture of Helen’s Concept Map

Also, it was observed that Helen was concerned about the structural relationship when she needed to link an unused concept for the concept map as John did. According to Helen:

(Question: “Why did you omit these concepts (discovery learning, reception learning, retention, and rote learning) in your [initial] authoring process?”) “I was not sure how I could put the concepts together as a chapter (chunk). Furthermore, I could not find any appropriate link for the concepts to any chapter (chunk) even as sub-
concepts. The concepts were not important to form a group. Indeed, they were not appropriate to make a smooth story.”

(Question: “What do you mean by a smooth story?”) “I mean that the entire content structure should form a reasonable logic to be learned for students. I could make that sequence or structure of what to teach, but the concepts did not fit my story line.” [From open-ended interview]

“I was thinking what to do with the unfamiliar concepts (that were not used in the Knowledge Organizer). I was thinking of making another group for the concepts (but Helen did not make another group, but rather linked them within her concept map).” [From stimulated recall verbal reporting regarding the concept mapping]

As John was, Helen also was concerned about the relationship between the concepts at a macro level of how they were interconnected. As a matter of fact, Helen’s scores of familiarity and understanding of the unused concepts were not very low. For instance, her scores for “rote learning” and “reception learning” were 2 and 3 for the familiarity scores and 3 and 4 for the understanding scores. However, both “discovery” and “reception learning” were rated as 5 for the familiarity and understanding scores. Therefore, although Helen stated that she omitted the four concepts because they were not familiar to her, at least two concepts were not unfamiliar but were rather very well familiar and understood. Consequently, even though Helen did not select the four concepts for the concept map, it did not indicate that she did not select them because of the unfamiliarity of the concepts. Rather, it should be interpreted that Helen could not find interrelationships with the four concepts according to her content structure.

Ryan. Ryan’s concept map had a different structure from those created by John, Sally, and Helen. His concept map had an associative structure as illustrated in Figure 5-10. In other words, his concept map was neither a tree structure nor a linear structure.
Indeed he did not apply the content structure he used with the Knowledge Organizer to his concept map. At first, he was trying to make his concept map with the same structure as the content structure he created using the Knowledge Organizer. However, while he was linking the concepts during the concept map process, he seemed to be confused by the complicated relationships between concepts.

Figure 5-10. Screen Capture of Ryan’s Concept Map

“At first I wanted to make this concept map look as I did with the Knowledge Organizer. However, I thought that the concepts could be connected all together. Even though I selected three concepts for the chapters using the Knowledge Organizer, I thought that the concepts
should be connected to each other because they were related concepts. Then, I linked the concepts if I found any relationships, regardless of the content structure I created with the Knowledge Organizer. However, I was confused by the links because I made too many links between concepts. Thus, I decided to restart to build a concept map; then, I initialized the screen.” [From stimulated recall verbal reporting regarding the concept mapping]

Once Ryan restarted the concept map, he did not care about the chapters and chunks that he had created through the Knowledge Organizer. Rather, he positioned the concept of “meaningful learning” in the middle of screen as a core concept. Then, he made links between the core concept and other concepts.

The structure of the concept map became, then, totally different from the content structure created with the Knowledge Organizer. For instance, Ryan chunked the concepts of “anchoring ideas”, “influence of knowledge structure”, and “readiness” under the concept of “cognitive structure” in his content structure using the Knowledge Organizer. However, “influence of knowledge” did not have a direct link to “cognitive structure” in his concept map. For another example, Ryan chunked the concept of “prerequisites of meaningful learning” with “meaningful learning” when using the Knowledge Organizer. However, the concept of “prerequisites of meaningful learning” was directly linked to “cognitive structure” as well as to “meaningful learning” in his concept map. In fact, Ryan put “prerequisites of meaningful learning” at the last chunk when using the Knowledge Organizer. The concept of “cognitive structure” was in the first chunk in his created content structure (See Figure 5-4). In other words, some concepts had been chunked in different groups for the content structure created with the Knowledge Organizer; however, the concepts were directly linked as if they were closely related in his concept map. Similarly, he grouped “rote learning” to “discovery learning” in the second chunk in the content structure created through the Knowledge Organizer.
However, “rote learning” was directly linked to “understanding” as well as to “discovery learning” in his concept map. His knowledge structure seemed inconsistent.

“While I was linking the concepts, I was reading the definition of concepts. If there was a relationship between concepts, I immediately linked them. Then, I realized that every concept could be related together... In the definition of understanding I saw the term of rote learning. I then linked understanding and rote learning. Well, those had been assigned to different chapters in the Knowledge Organizer. But, I thought that it would be better make a link between them (understanding and rote learning).” [From stimulated recall verbal reporting regarding the concept mapping]

From his verbal reporting, it seemed that Ryan might not have deeper understanding about the connectedness between the concepts. Rather, his concept mapping process depended on word information in the definition of the concepts. While he was reading the definition, if he found a word referring to another concept, he then linked them. It could be assumed that if a learner did not have deeper understanding of given concepts he or she may create irrational and inconsistent links.

Susan. To build a concept map, Susan first positioned the key concepts of the content structure she had created with the Knowledge Organizer. These concepts played a role as core concepts in her concept map. Then, she placed and linked other concepts to the core concepts. As illustrated in Figure 5-11, her cognitive map had a blended format of a tree structure and an associated structure. Susan’s concept map structure was fairly similar to that of the content structure created in the Knowledge Organizer. In addition, she made a couple of links to connect the chunks. She applied a tree and an associative structure at the same time to build her concept map.

After first positioning the core concepts, Susan selected the concepts that could support the core concepts. In other words, she tried to figure out how the other concepts
could support the core concepts. This strategy may explain how a learner constructs a knowledge structure.

**Figure 5-11. Screen Capture of Susan’s Concept Map**

“I was moving the concept boxes (anchoring ideas and assimilation theory) close to the concept of meaningful learning because they support meaningful learning taking place. Then, I realized that cognitive structure could be supported with those concepts.” [From stimulated recall verbal reporting regarding the concept mapping]
Susan seemed to believe that the concepts of “anchoring ideas” and “assimilation theory” had interrelationships between “meaningful learning” and “cognitive structure”. The role of this type of link would bridge different chunks of knowledge. Susan also demonstrated another interesting concept map process. She put the concept of “prerequisites of meaningful learning” with only one link to “meaningful learning”. She reported:

“I was moving this concept box (prerequisites of meaningful learning) under the concept of meaningful learning. But I put the concept box aside from the other concept boxes because this concept box (prerequisites of meaningful learning) had a relationship only with the concept of meaningful learning. It did not have substantial relationship with the other concepts.” [From stimulated recall verbal report regarding the concept mapping]

In other words, the concept of “prerequisites of meaningful learning” did not have an interrelationship with other concepts or chunks but, rather, had only one-directional relationship to the concept of meaningful learning. If a concept is too specific to another concept, then the specific concept might have very limited links with other concepts.

Jessica. Jessica’s concept map also had a blended format of a tree structure and an associated structure. First of all, she put the concept of “assimilation theory” at the top of her concept map because she believed that it was the core concept to explain Ausubel’s theory. After positioning the core concept, she expanded her concept map from there. In this sense, Jessica’s concept map could be characterized as a tree and a hierarchical structure. However, while she expanded the concept map, concepts were associatively linked. Figure 5-12 shows Jessica’s concept map.
Figure 5-12. Screen Capture of Jessica’s Concept Map

Jessica’s concept map showed an interesting structure at the bottom of her concept map. The concepts were expanding like a typical associated structure from the core concept. However, as the links went to the bottom of concept map there were only two concepts, which were multiply linked with other concepts.

“It was not easy to position the understanding concept because it could be linked to any other concept. What I was concerned about was that the concept of understanding was so general it could be linked to any other concept. But the problem was that the concept (understanding) was not a higher concept including other concepts. As a matter of fact,
understanding could be linked to any concepts dealing with types of learning because understanding would be an ultimate goal of any learning theory. Actually, I could link the understanding to the concepts related to learning (prerequisites of meaningful learning, meaningful learning, and rote learning), but I did not because it could make the concept map too complicated.” [From stimulated recall verbal reporting regarding the concept mapping]

In other words, Jessica perceived the concept of understanding as a kind of domain general knowledge rather than domain specific knowledge. She believed that every concept of learning was for understanding. Thus, the concept of understanding could be linked to any other concept. From Jessica’s case it would be assumed that if a learner perceived a concept as domain general knowledge, the concept could not be specified in terms of connectedness of knowledge to be transformed.

Summary. Several cognitive strategies for a concept map process were revealed. First, differentiating similarities and differences of concepts is important in constructing a concept map. This cognitive strategy would be more critical if a learner specifically builds either a tree structure or a hierarchical structure because those structures may not allow inter-relational links between different chunks. Second, understanding a macro-level relationship is more important than understanding individual concepts when making a conceptual framework of content structure as well as that of concept map. If a learner could not find an acceptable macro-level relationship from a certain of concept, it would be hard to figure out where the concept should be linked. Last, if a learner perceived a concept as domain general knowledge rather domain specific knowledge, the general knowledge may not be linked in a specific spot in a concept map. Likewise, if a learner perceived a concept as being too specific, then the concept might have very limited links with other concepts.
Theorized Model

The results from the Model Theorization Stage were integrated in a conceptual model illustrated in Figure 5-13. New cognitive components and relationships emerged, and a couple of modifications were made from the On-going Model (See Figure 3-5). However, many other components and internal processes of the On-going Model were verified even from the results of the Model Theorization Stage.

Authoring goal

It was identified that the most critical component of knowledge transformation was an authoring goal. The authoring goal, illustrated as (1) in Figure 5-13, served as a starting point to have a learner activate his or her mental effort to transform prior knowledge. As continuously observed from the Model Initiation and Elaboration Stages of the iterative model saturation process, the given authoring goal played a key role in determining what knowledge should be utilized and how to organize the utilized knowledge. The authoring goal also affected the operation of the Knowledge Organizer. In other words, the authoring goal was a critical cognitive component with which participants were concerned during the entire knowledge transformation process.

In the Model Theorization Stage, the authoring goal was briefly given to participants when they were told about the purpose of their participation at the very beginning of participation. Although the problem statement (See Figure 4-5) was not given to participants with detailed information at the beginning, participants were notified of what to do to develop a learning material for students about some concepts of Ausubel’s theory. The main objectives of the authoring goal were “to develop a learning material” and “to teach graduate students.” By being told the two objectives, participants activated two different types of knowledge: 1) content knowledge about Ausubel’s theory and 2) instructional knowledge of how to deliver a certain body of knowledge to students.
Content knowledge

As a main source of knowledge transformation, the role of content knowledge was apparently critical. The participants’ content knowledge was activated only through identifying a given authoring goal, as illustrated as (2) in Figure 5-13. From the Model Initiation, Elaboration, and Theorization Stages, it was continuously observed that different understanding of the concepts significantly affected the process of knowledge transformation. The results from the Model Initiation and Elaboration Stages roughly assumed the importance of content knowledge in the knowledge transformation process. However, the results from the Model Theorization Stage could more precisely delineate the importance of content knowledge.

In the process of knowledge transformation, it did not matter how many pieces of concepts participants could precisely recall or retrieve from their memory. Rather, more important was the degree of understanding of internal relationships within the concepts. This rationale was supported by the findings from the analysis of the content structures participants created using the Knowledge Organizer. For example, the concepts with lower scores of familiarity and understanding could be used as key concepts to include sub-concepts. In other words, even if a learner may not be able to precisely recall or understand a certain concept, if the learner understood internal relationships between concepts, the not-precisely-recalled or ill-understood concept still would be helpful to restructure his or her prior knowledge into a new form of knowledge structure.

The notion of importance of internal relationships between concepts then leads to a question of why the understanding of internal relationships is important. A possible answer to the question can be obtained from the concept of a schema that explains how we store and retrieve knowledge. According to Jonassen and his colleagues (1993), a schema contains interrelationships between schemas.
“A schema for an object, event, or idea is comprised of a set of attributes or slots that describe and therefore help us to recognize that object or event. These slots contain relationships to other schemas. It is the interrelationships between schemas that give them meaning. (p. 6)”

These interrelationships help learners understand the meaning of a certain body of knowledge. Similarly, Sweller (2003) emphasized how the interrelationships between schemas could facilitate learning. According to Sweller, the relational understanding of concepts or schemas will help learners to categorize knowledge in the way it will be used.

“Knowledge is stored in long-term memory in schematic form, and schema theory describes a major learning mechanism. Schemas allow elements of information to be categorized according to the manner in which they will be used (p. 221).”

In other words, the processing of information requires “the manipulation of schemas, which can act as interacting elements, in working memory. That manipulation can result in learning, which consists of the creation of new, higher order schemas and automation (Sweller, 2003, p. 222).” The role of content knowledge would have an effect on organizing concepts in two ways. First, understanding of content knowledge affects comprehension of the internal relationships of the concepts. Second, internal relationships of the concepts then affect the goal configuration, which leads to a direction of knowledge transformation. Thus, when the content knowledge was named as a personalized mental representation of the knowledge by Chen and Ennis (1995) and Moallem (1998), the personalized mental representation indicated the learner’s different levels of understanding of interrelationships between concepts, which would lead to a different way of knowledge transformation. However, it would be impossible to identify how differently each learner understands a certain area of knowledge until the learner transforms his or her prior knowledge to meet a given goal, because the role of content
knowledge is not be activated until an authoring goal is given in the knowledge transformation process. Only when a learner identifies an authoring goal is the content knowledge activated to transform itself to meet the goal.

Figure 5-13. Theorized Model of Knowledge Transformation Through an Authoring Tool
Instructional knowledge

Once participants identified the authoring goal, they activated instructional knowledge of how to structure and deliver the content knowledge as well as content knowledge of what should be organized. The content knowledge, illustrated as (3) in Figure 5-13, played a role as a main source of knowledge transformation. The instructional knowledge played a role as a guideline of organizing the content knowledge.

The existence of instructional knowledge was identified from the Model Elaboration Stage, but the instructional knowledge was considered activated when participants were operating the Knowledge Organizer. However, the Model Theorization Stage revealed that the instructional knowledge had an effect at an earlier stage of the knowledge transformation process. In other words, when participants identified the authoring goal, the identification of the authoring goal triggered content knowledge and instructional knowledge simultaneously. Participants’ verbal reporting supported that their instructional knowledge was activated to determine how the concepts should be organized even when participants were rating their familiarity with and understanding of the concepts.

“I already was thinking of how the concepts should be organized. When I entered this screen (of the concept of influence of knowledge structure), I immediately thought that this concept clearly should belong to the concept of cognitive structure.” [Ryan’s stimulated recall verbal reporting regarding the familiarity with and understanding of the concepts]

“At first I thought that this concept (retention) was a little unfamiliar to me. However, soon after I could understand the concept because I could find a relationship between this one and the concept of cognitive
structure (this concept was shown to her earlier).” (Jessica chunked the concept of retention and cognitive structure together). [Jessica’s stimulated recall verbal reporting regarding the instrument rating process]

“I thought that this concept (meaningful learning) would be the biggest one. Then, I was trying to link other concepts to this one. I was thinking how this concept (meaningful learning) should be linked to others.” [Sally’s stimulated recall verbal reporting regarding the instrument rating process]

“I was thinking about what concept would be the highest concept to cover other sub-concepts. When I was reading this concept (meaningful learning), I thought that this would be the highest one that I had been looking for. I thus wanted to pay more attention to read this concept because I expected that there might be some important cues in its definition, which I needed to use to link another concepts.” [Helen’s stimulated recall verbal reporting regarding the instrument rating process]

Although instructional knowledge was activated at the earlier stage of the knowledge transformation process, the participants’ instructional knowledge still affected participants when they were operating the Knowledge Organizer, as identified from the Model Elaboration Stage. The impact of instructional knowledge was observed to have a more intense effect during use of the Knowledge Organizer. During the rating of the familiarity with and understanding of the concepts, understanding of the concepts was the higher priority for participants while they considered how to organize the concepts (instructional knowledge). However, when participants needed to operate the Knowledge Organizer, they assumed that comprehension of the concepts was complete. They then
wanted to allocate more mental efforts to the use of instructional knowledge. In other words, at the earlier stages of knowledge transformation, participants allocated more cognitive efforts to activate their content knowledge than their instructional knowledge.

**Preliminary modification of knowledge structure**

Preliminary modification of knowledge structure was a newly emerged cognitive component, which had not been identified from the Model Elaboration Stage. This new cognitive component was illustrated as (4) in Figure 5-13. Once participants identified the given authoring goal, they were trying to figure out how to modify their knowledge structure to transform it into a hypertext document. While participants were using the instrument to rate their prior knowledge, this preliminary modification took place. Since the purpose of authoring was already given in the introduction session of this study, the authoring goal had begun to affect participants’ comprehension of the concepts presented by the instrument as they began to consider how to achieve the authoring goal.

It was apparent that content knowledge and instructional knowledge were coordinating for the preliminary modification of knowledge structure. After the authoring goal activated their content knowledge and instructional knowledge, participants were observed to begin to modify their knowledge structure for transformation. Yet, there was no mediation by the functions of an authoring tool, the modification of knowledge structure needed to remain a preliminary form of knowledge transformation. The main features of this preliminary modification of the participants’ knowledge structure occurred as the following sequence: 1) comprehension of the concepts, 2) adjustment of the participants’ prior knowledge of the concepts, and 3) configuration of the interrelationships of the concepts.

When a concept was presented to participants while rating their scores of familiarity and understanding of the concepts, they tried to comprehend the presented concept at first. It seemed that they wanted to be sure of what they knew, prior knowledge, and what the presented concepts meant. If there were gaps between their
prior knowledge and the presented concepts, participants were trying to reduce the gaps by adjusting their understanding and prior knowledge structure to the concepts.

“*I was reading the concepts and thinking of how they were identical as I learned them before...in this screen (the concept of learning material) I thought that it was unfamiliar to me. But, I could understand as I read it.*” [John’s stimulated recall verbal reporting regarding rating with the instrument]

(Verbal prompt: “What were you doing?”) (Helen was watching herself staring at the computer screen of the concept of readiness in the instrument session. She was making a long pause in her verbal reporting; thus, the researcher’s verbal prompt was given.) “Um...I thought that this concept (retention) was not familiar with what I already knew before. I was trying to understand the concept. Actually, I thought that I understood it. But it was not easy to figure how this concept could be related to the other concepts.” [Helen’s stimulated recall verbal reporting regarding rating with the instrument]

“I was thinking of two things when I was rating the instrument items of familiarity and understanding about the concepts. First, I was trying to link between what I learned and the presented concepts. Then, second, I was thinking a lot about the relationships within the concepts.” [Sally’s stimulated recall verbal reporting regarding rating with the instrument]

The preliminary modification of a knowledge structure would be like constructing a mental model to meet the purpose of the authoring goal. Participants were preparing to make a meaningful structure to transform their knowledge into a hypertext, yet the
knowledge transformation was in a preliminary form. While they were reading the presented concepts in the instrument, participants were comparing between their prior knowledge and the presented concepts, reducing the gap of what they did not know before, linking what they understood to the knowledge structure in their long-term memory, and verifying their understanding. These cognitive processes were not static mental representations of their knowledge but comprised a very dynamic construction process of “running the model to test out possible outcomes in advance of some action (Ehrlich, 1996, 239)”. Although the participants’ mental models were constructed in a preliminary form, participants already began to transform their knowledge structure for the authoring goal.

**External representation by tool regulation**

The external representation by tool regulation was illustrated as (5) in Figure 5-13 and identified again similar to the result of the Model Elaboration Stage. Even after participants constructed their own preliminary modification of their knowledge structure, when they had to operate the Knowledge Organizer, the tool functions played a role in regulating the preliminary modification of their knowledge structure. In other words, although the authoring goal, content knowledge, and instructional knowledge changed a mental representation through the preliminary modification of knowledge structure, the preliminary modification was not yet externalized. In order to externalize the modified mental representation, participants had to follow the authoring tool’s functions. Consequently, the changed mental representation needed to be altered by the ways an authoring tool allowed the presenting of knowledge.

(Question: “Was there any trouble in using the Knowledge Organizer?”) “I wish I could make 3rd level sub-concepts. I mean that the Knowledge Organizer only had two levels: 1) chapters and 2) sub-chapters. But, sometimes I needed to make a group of concepts at a 3rd
level. It honestly bothered me to only make two levels.” [From Jessica’s open-ended interview]

(Question: “If you were using PowerPoint to build a similar material with the same concepts, what would be different from using the Knowledge Organizer?”) “I would like to insert pictures to show the relationships between concepts. I could only use text with the Knowledge Organizer, and actually it was not easy to organize the concepts as a learning material with the Knowledge Organizer.” [From Sally’s open-ended interview]

“There were some concepts, which could be linked to more than two chapters. However, I had to pick only one concept to be linked because the Knowledge Organizer did not allow me to do so.” [From Susan’s stimulated recall verbal reporting regarding the Knowledge Organizer]

Internal modification of the knowledge structure

The internal modification of the knowledge structure was observed again as it was in the Model Elaboration Stage. Furthermore, the analysis of the data of the Model Theorization Stage revealed how the internal modification of the knowledge structure was working, and it was illustrated as (6) in Figure 5-13.

First of all, the internal modification of the knowledge structure was the core cognitive activity of knowledge transformation. There were four cognitive resources to execute the internal modification of the knowledge structure. They were: 1) the authoring goal, 2) content knowledge, 3) instructional knowledge, and 4) external representation by tool regulation. These cognitive resources were dynamically cooperating for the internal
modification of the knowledge structure. Moreover, this internal modification articulated the preliminary modification of the knowledge structure.

During the internal modification process, the authoring goal continued to have a great impact on the knowledge structure. Participants continued to be concerned about how to meet the goal. Also, instructional knowledge played a greater role than it played during the preliminary modification process. As a matter of fact, during the preliminary modification process, participants paid more attention to adjusting their mental representations given their new or refreshed understanding of the concepts and the authoring goal than they paid to instructional knowledge. When participants entered the stage of using the Knowledge Organizer, they used their instructional knowledge more thoroughly. It was assumed that participants comprehended the concepts upon completing the preliminary modification process. Then, participants switched their cognitive efforts more toward using their instructional knowledge while they were operating the Knowledge Organizer. In the meantime, participants applied tool functions to externalize their internal modification of their knowledge structure.

Regarding chunk size and the sequence of chunks, four cognitive strategies were observed during the internal modification of the participants’ knowledge structure: 1) configuring interrelationships of the concepts, 2) identifying a higher concept to make a chunk, 3) arranging from introductory concepts to application concepts, and 4) constructing a meaningful instructional story to make an appropriate sequence. First, most participants were trying to configure interrelationships of the concepts. In the earlier stage of knowledge transformation, when participants were rating their familiarity with and understanding of the concepts, they were trying to comprehend the presented concepts. In this comprehension process, participants were also trying to configure the interrelationships of the concepts. However, due to the cognitive overload of the comprehension process, they could not put sufficient mental efforts toward configuring the interrelationships. When, however, participants could more fully concentrate on manipulating the given concepts using the authoring tool, they exerted much greater cognitive effort to configure the interrelationships.
Second, the configuration of interrelationships was associated with identifying higher concepts. While participants were configuring the interrelationships, they were also trying to identify higher concepts. It seemed that both of these two cognitive activities were taking place simultaneously.

“I was carefully reading the concepts on the screen while I was thinking which concept could be higher one. Um…I was reading the definition of anchoring ideas. I was not sure whether this concept (anchoring ideas) could be a higher concept or a subordinate one. Also I was thinking where this concept should be presented. I mean whether this concept should be presented either at the earlier or later sequence.” [From Helen’s stimulated recall verbal reporting regarding operating the Knowledge Organizer]

“I was confused because I was not sure if I selected appropriate key concepts. Actually, I selected three key concepts. It was the same as I had thought during the instrument stage. However, I still was not sure. I was thinking about the hierarchy between three key concepts. What I was most concerned about was identifying if there were any concepts, which could be regarded at the same level of hierarchy.” [From Ryan’s stimulated recall verbal reporting regarding operating the Knowledge Organizer]

Third, most participants were arranging the concepts from introductory concepts to application concepts. The introductory concepts contain background knowledge of the presented concepts. For instance, as identified from the content structure of the Knowledge Organizer (See Table 5-9), most participants selected the concept of “cognitive structure” as their first chapter (chunk). Participants seemed to think that
“cognitive structure” would provide a foundation for the remaining concepts in Ausubel’s theory.

Last, but most important, participants were constructing a meaningful instructional story to make an appropriate sequence. There were two main factors that affected their making an appropriate sequence of the concepts: 1) goal configuration and 2) instructional knowledge. First, goal configuration is a strategic plan to achieve the given authoring goal. For instance, John stated that he wanted to create a sequence for chunks from an information processing perspective. He explained that each chapter represented how information came to a learner and was assimilated into his or her cognitive structure. Then, finally, the last chapter was to explain how discovery learning could take place by means of meaningful learning (See Figure 5-1). For another example, Sally stated that she wanted to provide conceptual definitions first. Then, the last chapter was to provide how the conceptual definition could be applied (See Figure 5-2). All of the participants had their own logic for arranging the concepts. Second, instructional knowledge provided another strategic plan to achieve the goal configuration. Once the authoring goal was configured, participants started to make a sophisticated plan for arranging the concepts. During this process, participants had to decide what concepts should be chunked, linked to a key concept, or selected as a key concept. Their instructional knowledge generated more detailed rules to transform participants’ knowledge into a hypertext document. For instance, Helen stated:

“I was thinking of a flow for my instruction. First, I wanted to let my students understand what meaningful learning was; then, I wanted to show how to develop learning material to make meaningful learning happen.” [From Helen’s stimulated recall verbal reporting regarding operating the Knowledge Organizer]

(Question: “What was the rationale of your instructional plan?”) “I thought that it would be important to provide more general terms or
background knowledge first. Thus, I put cognitive structure as a first chapter. Then, I wanted to explain about meaningful learning because it was the core concept of Ausubel’s theory. Last, I wanted to give students concepts of how learning material should be developed to implement meaningful learning. As a matter of fact, I thought that to understand the concept of learning material was to understand how to apply the concept of meaningful learning.” [From Helen’s open-ended interview]

All of the participants reported similar mental activities when outlining detailed rules of selecting, chunking, or linking the concepts. During these mental activities, participants exhaustively spent their mental efforts in reviewing their knowledge structure and verifying their understanding.
CHAPTER 6
DISCUSSION

Evolutions from the Model Elaboration Stage

The outcome of the Model Theorization Stage resulted in a couple of modifications of the cognitive model of knowledge transformation in authoring hypertext from the Model Elaboration Stage. In addition, the Model Theorization Stage could validate many cognitive components identified from the Model Elaboration Stage. Three major modifications were made in the cognitive model of knowledge transformation: 1) the role of the authoring goal, 2) the role of the instructional knowledge, and 3) the existence of the preliminary modification of knowledge structure. The authoring goal was identified as activating the participants’ content knowledge and their instructional knowledge simultaneously, though the authoring goal had an effect on the entire process of knowledge transformation. Also, it was identified that the impact of instructional knowledge affected knowledge transformation at the very earlier stage of knowledge transformation. Lastly, but most importantly, the Model Theorization Stage identified that participants were creating preliminary modification of their knowledge structure in advance of their authoring process in which they used the Knowledge Organizer. Based on these modifications and validated cognitive processes, the cognitive model of knowledge transformation in authoring hypertext was constructed.

Additionally the theorized model of knowledge transformation provided answers for three questions raised from the Model Elaboration Stage. The questions were: 1) How
does interaction with the authoring tool affect knowledge transformation?, 2) What are the cognitive strategies being used in the knowledge transformation process?, and 3) What are the specific roles of the participants’ instructional knowledge?.

The first question was to identify the relationship between the functions of the authoring tool and the cognitive processes of knowledge transformation. It was observed that the Knowledge Organizer helped participants reduce their cognitive load during the knowledge transformation process. In using the Knowledge Organizer participants had to select key concepts to form chapters among the presented concepts, then they had to make a sequence for the selected key concepts, referred to as a chapter list. After sequencing the key concepts, participants had to link sub-concepts to the key concepts. Linking sub-concepts required high cognitive effort to determine what concepts should or should not be linked.

In fact, most of the participants of the Model Theorization Stage reported that it was not easy to do. While participants experienced high cognitive load in selecting and linking sub-concepts, they tended first to select an easier key concept from the chapter list to link with sub-concepts, regardless of the chapter sequence. Since participants were able to see what key concepts should be linked with sub-concepts, they could evaluate what key concepts would be easier or harder to link with sub-concepts. A key concept that appeared more difficult to link might require more mental effort to select and link sub-concepts. Because of this reason, participants wanted to work on an easier chapter first while harder chapters remained in the chapter list of the Knowledge Organizer. After completing the easier chapter, participants could allocate more of their cognitive resources to concentrate on the concepts that were harder to link.

The second question was to delineate cognitive strategies in the knowledge transformation process. The most frequently used cognitive strategy was comparing between one’s own prior knowledge and the presented concepts to identify if there was discrepancy between them. If participants found a gap between what they knew and what the presented concepts meant, they had to figure out how to assimilate the presented concepts into their knowledge structure. It was observed that if there were relatively
many gaps between prior knowledge and presented concepts, participants could be easily confused with understanding the interrelationships between concepts.

The third question was to specify the role of instructional knowledge. As mentioned in the previous chapter, the participants’ instructional knowledge affected the preliminary modification of their knowledge structure and the operation of the authoring tool. Specifically, the participants’ instructional knowledge was closely related to how they structured and delivered their content knowledge.

Knowledge Searching Process

At the beginning of the transformation, the authoring goal was identified as activating the content knowledge. The activation by the authoring goal triggers what knowledge should be retrieved from participants’ long-term memory and how the activated knowledge should be organized. The activation process by the authoring goal is similar to the spread of activation through semantic networks. Regarding the process of activation of semantic networks, according to Jonassen and his colleagues (1993), when a learner searches his or her semantic network, “the mind starts at the nodes identified by the input words and spreads through all of the links connected to those nodes to other nodes. As nodes are activated, they are tagged so that the processor can retrace the path to the starting node. (p. 7)” In the activation process, a key feature to maintain the activation is semantic similarities between nodes or concepts because the strengths of nodes increase the possibilities of being activated in searching the semantic networks.

The activation of the knowledge searching process is also important from the aspect of the knowledge transformation process because the knowledge searching process mainly occurs with prior knowledge in the form of a semantic network stored in long-term memory. Particularly, it would be important to explain how a learner activates the knowledge searching process while the authoring goal is executing and monitoring the
entire knowledge transformation process. The authoring goal activates the knowledge searching process through semantic networks at any time if it is necessary for successful knowledge transformation. The following section attempts to propose some possible answers.

Before proposing potential answers to the question above, it should be noted that the results of this study were conducted with a limited number of concepts. This means that participants had a limited number of resources to be transformed. The limited number of resources may, thus, require relatively less mental operations than would a larger number of resources. Additionally, this study investigated how prior knowledge is transformed rather than how knowledge acquisition takes place. Therefore, the answers to the questions might be limited to knowledge transformation involving prior knowledge.

The activation of the knowledge searching process in knowledge transformation should be analyzed at two levels: 1) the concept level and 2) the structure level. If a learner is searching for a definition of a concept for knowledge transformation, the learner should activate a concept-level searching process through his or her semantic networks. However, if a learner is searching for interrelationships between concepts, the learner should activate a structure level searching process through his or her semantic networks.

**Concept level knowledge searching**

Regarding the activation of the concept level searching process, the results of the Model Theorization Stage revealed that some participants paid more attention to word-level information in the definitions of presented concepts. As reported earlier in the previous chapter, when participants did not quite understand a certain concept, they were trying to find word cues in the concept’s definition for their understanding. By activating this type of knowledge searching process through the learner’s semantic network, the learner also could be able to relate the concept to other concepts. However, this relationship only depends on word-level cues within the definition.
The concept level searching process may be terminated relatively soon because the goal of the search is limited to understanding an individual concept rather than understanding the interrelationships between concepts. Participants in the Model Theorization Stage were at times able to understand a relationship between two concepts through the concept level searching process; however, their understanding of the relationship was very superficial, like a word-to-word relationship rather than structural understanding of how other concepts were interrelated. In the concept level searching process, participants’ cognitive attention was focused on grasping a definition of a concept. Therefore, once participants thought they had gasped the definition, the knowledge searching process would be terminated. It was not necessary to continue the knowledge searching process. In other words, the activation of the concept level searching process would not last long but would rather tend to be finished in a short time.

The concept level knowledge searching process was observed in Ryan. He was linking the presented concepts in terms of word information in the definitions of the concepts. When he was reading the concepts in order to link the concepts or find relationships between the concepts, he configured the relationship by word information in the concept. His linking process was limited to a closest concept from the starting concept. Ryan reported that:

“The last sentence (in the concept of rote learning) was saying that rote learning could occur in discovery learning. I was thinking “Aha! I see”. But, I was wondering if it really was correct.” [From Ryan’s stimulated recall verbal reporting regarding the instrument rating process]

Although Ryan was not sure of the relationship between the concepts of “rote learning” and “discovery learning”, he grouped these two concepts into the “assimilation theory” chunk in his content structure when using the Knowledge Organizer (See Figure 5-4). The “assimilation theory” chunk in the content structure he created using the
Knowledge Organizer consisted of three subordinate concepts of “discovery learning”, “reception learning”, and “rote learning”. He discovered a word-level relationship between the concepts when organizing the presented concepts using the Knowledge Organizer. Consequently, he decided to put the concepts of “rote learning” and “discovery learning” together. Regarding the concept of “reception learning”, Ryan reported that:

“I did not know about the reception learning concept. But, after reading the concept, I was thinking that the explanation was obviously right. Was it specifically explained in the textbook? (He asked the researcher)” [From Ryan’s stimulated recall verbal reporting regarding the instrument rating process]

He apparently was not familiar with the concept of “reception learning”. However, he put “reception learning” and “rote learning” together in his content structure.

“I was thinking that reception learning and rote learning were the same level concept.” [From Ryan’s stimulated recall verbal reporting regarding operating the Knowledge Organizer]

His cognitive process in creating the “assimilation theory” chunk was reported in a later verbal reporting:

“If there was the term cognitive structure in the definitions, I put them (concepts containing the term cognitive structure) together as a group. Similarly, if any concept explained about a sort of learning process, I chunked them into a chapter of assimilation theory. Thus, the discovery learning was grouped into the assimilation. Also, the concepts of reception learning and rote learning were chunked into the assimilation
theory chapter because discovery learning was linked to the assimilation theory.”

[From Ryan’s stimulated recall verbal reporting regarding operating the Knowledge Organizer]

In summary, the subordinate concepts of the “assimilation theory” chunk were being grouped by concept-to-concept relationships. First, Ryan found that the concept of “rote learning” could occur in “discovery learning” during the instrument rating session. Second, he thought that the concepts of “rote learning” and “discovery learning” could be linked. Third, although he was not quite sure about the concept of “reception learning”, he thought “reception learning” and “rote learning” were similar when he was operating the Knowledge Organizer.

Also, while Ryan was operating the Knowledge Organizer, he was locating concepts dealing with any sort of learning. If there were concepts related to learning, Ryan grouped them into the “assimilation theory” chunk. The concept of “discovery learning” was grouped into the “assimilation theory” chunk because “discovery learning” was dealing with learning. Then, Ryan grouped “rote learning” into the “assimilation theory” chunk because “discovery learning” was already grouped into the same chunk. Additionally, “reception learning” was grouped into the same chunk because he thought “reception learning” and “rote learning” had a relationship. Finally, Ryan formed the “assimilation theory” chunk with the concepts of “discovery learning”, “reception learning”, and “rote learning”. Ryan’s activation of the knowledge searching process took place concept-by-concept. When he found word information, he chained the findings. Ryan did not spread out the activation of the searching process but rather made a segment of activation of the searching process.

**Structure level knowledge searching**

In contrast to the concept level activation of the knowledge searching process, the structure level searching process involves searching for information with a structural
frame of how to organize concepts. Whereas the concept level searching process is employed for a conceptual understanding, the structure level searching process is used to understand the interconnectedness of concepts. The concept level searching process is activated at the moment a concept is understood, and the process is spread out through very limited numbers nodes of semantic networks. Thus, the knowledge searching process is limited node-by-node. On the other hand, the structure level knowledge searching process is activated to scan interrelationships among concepts, and the process is spread out across the chunks of semantic networks that consist of a set of nodes.

The structure level searching process was observed in Sally. She activated the searching process to locate appropriate concepts with a framework of what kinds of concepts should be searched. Sally made a plan of how to divide chapters during the instrument rating session.

“I was thinking of the relationship between schema and meaningful learning. Thus, I decided to make two chapters. Actually, it was not an easy job for me. It took a long time to do.” [From Sally’s stimulated recall verbal reporting regarding the instrument rating process]

Once she established how chapters should be divided, when she was reading the presented concepts, she paid careful attention to figure out the relationships between the concepts. Although she already made a plan of organizing chapters, she was rethinking the plan when she was operating the Knowledge Organizer.

“This screen was to [choose key concepts for the] chapters. I was reading the concepts. I spent a long time here. I was worrying about how to divide the concepts into chapters. While I was reviewing the present concepts, I decided on cognitive structure as one chapter. I thought that this concept might represent a heading chapter. Then, another chapter should be about meaningful learning.” [From Sally’s
stimulated recall verbal reporting regarding operating the Knowledge Organizer

Her concerns were for how chapters should be grouped. It seemed that she apparently paid more attention to structural relationship rather than to an understanding of each concept. As she continued to operate the Knowledge Organizer, she refined her plan for organizing chapters.

“There were various types of concepts dealing with learning. I was thinking of how to group the concepts dealing with learning. I was thinking of two ways. First, I could explain the meaningful learning by comparing the various learning related concepts. Then, I could explain what would be advantages of meaningful learning. Second, I could divide the concepts into two chapters. The first chapter was to explain about the cognitive structure, and the second chapter was to explain about the meaningful learning.” [From Sally’s stimulated recall verbal reporting in operating the Knowledge Organizer]

Finally, she grouped two chapters of “cognitive structure” and “meaningful learning” (See Figure 5-2). Since the Knowledge Organizer did not allow participants to make a sequence for subordinate concepts, the sub-concepts she assigned to each chapter were displayed in an alphabetical order. However, Sally constructed her concept map with consideration for the sequence of sub-concepts. According to her concept map (See Figure 5-8), she placed the concepts of “rote learning”, “reception learning”, and “discovery learning” on the right side of “meaningful learning”. According to her verbal reporting, this arrangement was representing that the three concepts of “rote learning”, “reception learning”, and “discovery learning” were grouped to compare their differences from “meaningful learning”.
As a matter of fact, both Ryan and Sally put several of the same concepts together but in different ways. Ryan chunked the concepts of “discovery learning”, “reception learning”, and “rote learning” into the chapter of “assimilation theory”. In the same way, Sally chunked the concepts of “discovery learning”, “reception learning”, and “rote learning” as sub-concepts for the chapter of “meaningful learning”, though she put more subordinate concepts into the chapter. Although Ryan and Sally grouped the same concepts into a chapter, their cognitive processes to decide what concepts should be grouped were obviously different.

**Definition of Knowledge Transformation Through an Authoring Tool**

At the beginning of this study, knowledge transformation through an authoring tool was defined as follows:

*Knowledge transformation through an authoring tool comprises the mental activities and processes associated with interaction with an authoring tool to refine and relocate prior knowledge to develop and create meaningful knowledge artifacts in the form of a computerized document to solve a given problem.*

In this definition, three aspects were considered. First, internal modification of prior knowledge should take place corresponding to “mental activities and processes of refining and relocating prior knowledge” in the above definition. Second, externalization of the modified mental structure should be followed through the authoring process corresponding to “develop and create meaningful knowledge artifacts” in the above definition. Third, a goal to transform prior knowledge should be given corresponding to “to solve a given problem” in the above definition.
The result of this study proposes a new definition of knowledge transformation through an authoring tool as the following:

\textit{Knowledge transformation through an authoring tool is a process of reorganizing prior knowledge into a meaningful knowledge structure for the purpose of the authoring goal as the authoring tool enables the user to present information.}

This new definition consists of four main components of knowledge transformation: 1) the authoring goal, 2) content knowledge, 3) instructional knowledge, and 4) the authoring tool’s functions. Those components were reciprocally coordinating to transform prior knowledge into a hypertext document.

First, an authoring goal should be given to a learner; then, by identifying the goal, he or she is able to activate content knowledge and instructional knowledge. It is referred to “the purpose of the authoring goal” in the new definition.

Second, once the authoring goal is given, the goal activates domain knowledge to be transformed. The domain knowledge is content knowledge to be transformed as a main resource of knowledge transformation. It is referred to as “prior knowledge” in the new definition.

Third, when the content knowledge is activated by the authoring goal, a learner starts thinking about how the domain knowledge should be organized in a meaningful way. The knowledge transformation is not merely arranging prior knowledge but carefully reorganizing it because the transformed knowledge should still be meaningful for the purpose of the authoring goal. This characteristic is referred to as “a meaningful knowledge structure” in the new definition.

Last, knowledge transformation should finally be externalized in a format of an artifact generated by an authoring tool. In other words, a final form of knowledge transformation should be a product of the authoring tool. This means that the ways of presenting information allowed by the authoring tool regulate how the transformed
knowledge is externalized. This is referred to as “as the authoring tool enables the user to present information” in the new definition.

This new definition emphasizes the role and process of the four components. Knowledge transformation through an authoring tool can be carried out only when these four components are interactively coordinating each other. If there is a lack of goal identification, a learner may not be able to activate appropriate domain knowledge. Also, even if a learner has a clear understanding of the authoring goal with adequate domain knowledge, if the learner does not have proper instructional knowledge to determine how
the domain knowledge is to be reorganized, knowledge transformation may not be sufficiently carried out. Finally, the way of presenting information allowed by a given authoring tool affects a final format of knowledge transformation. Figure 6-1 illustrates the mutual relationships among four main components of knowledge transformation.

Implications

For the instruction of knowledge transformation

The result of this study may suggest instructional implications for those who want to apply the idea of learning by authoring hypertext/hypermedia. As mentioned earlier in this chapter, the knowledge searching process was identified as one of the most important cognitive processes in transforming prior knowledge. Two types of knowledge searching processes were identified. If a learner does not have adequate understanding of given concepts, the lack of understanding leads the learner to activate the knowledge searching through node-by-node in semantic networks. Therefore, learners under this situation may need to have direct guidelines to understand given concepts.

It would be hard for learners under this situation to learn interrelationships within the domain knowledge. Knowledge transformation is very dynamic mental activity, which might cause cognitive overload. Consequently, learners with a lack of understanding or poor prior knowledge cannot allocate enough cognitive resources to operate the inter-relational knowledge. Therefore, from an instructional point of view, it would be helpful for the learner to provide linear representations of domain knowledge. As argued by Kozam (1991), “linear representations have structural cues that direct the user’s movement through the information.” (p. 23) By providing linear representations, learners with poor prior knowledge can enhance their understanding of the domain knowledge to be transformed.
In contrast, learners with sophisticated domain knowledge may frequently activate the knowledge searching process at the structure level during knowledge transformation. Their activation of the knowledge searching process spreads out through chunks of semantic networks because their cognitive concerns are for searching interrelationships within domain knowledge. During the knowledge searching process at the structure level, learners construct various mental models until they find sound interrelationships. In the meantime, the construction of various mental models forms the preliminary modification of their knowledge structure. The forming process of preliminary modification requires high cognitive load to operate complex mental activities because “mental models allow people to draw inferences, make predictions, understand phenomena, decide which actions to take, and experience events vicariously (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000, p. 274)”.

Subsequently, a learner is running various mental models, and perhaps then changing the internal mental representation (Ehrlich, 1996, p. 239). In order to help learners to deal with this dynamic process, a conceptual or theoretical structure for various authoring goals should be guided (van Merrienboer, 1997).

The participants of the Model Theorization Stage were asked what they would like to alter in the content structure of Knowledge Organizer if they had to organize the given concepts for non-novice students instead of the novice students as described in the problem statement (See Figure 3-2). Most of participants answered that they would change the content structure because their target audience had been changed. This meant that a different authoring goal required participants to modify the direction of knowledge transformation. Therefore, it would be important to increase the flexibility of structural knowledge for the domain knowledge to facilitate knowledge transformation. The restructuring process in knowledge transformation needs high-level flexibility to figure out the interconnectedness of domain knowledge in multiple ways.

For the design of an authoring tool
Regarding the design of an authoring tool, three implications would be possible: 1) reducing distracting features, 2) providing job aids to reduce cognitive load, and 3) avoiding disorientation. First, it is important to reduce distracting features in an authoring tool. The authoring process of knowledge transformation demands an extremely high cognitive load in learners. Even if learners had prior knowledge, it still requires high cognitive load. Thus, the effective management of removing distracting features from an authoring tool should be considered. The distraction may come from functions either too complicated or unnecessary for operating the authoring tool. As Ray (1999) argued, the functions of authoring tool should remain the focus of the learner’s attention. The distractive features interfere with the cognitive process by causing split-attention. Consequently, split-attention imposes an extraneous cognitive load (Cerpa, Chandler, & Sweller, 1996).

Second, an authoring tool should provide job aids to reduce cognitive load. As described earlier in this chapter, participants in the Model Theorization Stage tended to organize an easier chapter first, while chapters more difficult to organize remained in the list of chapters. Participants knew that they did not need to worry about what chapters should be organized because the list of chapters in the Knowledge Organizer held the information of what chapters should be organized. Then, participants could switch their mental efforts to working on easier chapters first. This type of job-aid might be helpful for learners because they could save mental efforts for harder chapters by finishing relatively less intensive tasks first.

Third, an authoring tool needs to provide a tracking function to indicate what tasks a learner is working on or what the authoring goal is. If a sequence of tasks can be provided to a learner, it would be a good tracking function for him or her. Basically, the tracking function is to prevent learners from becoming disoriented regarding what a learner is doing with the authoring tool. The documentation of hypertext/hypermedia allows learners non-linear and flexible access to information (Altun, 2000). Consequently, the authoring process for hypertext/hypermedia requires more interactive and overt ways of thinking. In this situation where learners are dealing with a dynamic thinking process,
learners can get easily lost in their task sequence. The tracking function helps the learners to know what they were doing and what they do. It may look similar to the job-aids to reduce cognitive load. The difference is whereas the job-aids were closely related to handling the domain knowledge, the tracking functions are more likely to support the work processes and answer questions of what to do.

**Limitations of the Study**

Several criticisms can be raised against collecting the data and analyzing the results of this study as proposed. The first and most important issue to consider is generalizability, and this lack of generalizability can be raised from two sources: 1) the stimulated recall verbal report as a main method to collect the data and 2) the use of grounded theory as a research framework to analyze the data.

First, the main method of collecting data for this study was the stimulated recall verbal report that was based on participants’ verbal report while they are watching a video recording of their performance of a given task. Although the stimulated recall verbal report is not exactly the same as a concurrent verbal report, also known as a protocol analysis, the stimulated recall verbal report may have the same limitations as a protocol analysis. As Ericsson and Simon (1993) pointed out, a protocol analysis can collect only information in focal attention. Thus, some important aspects may not be verbalized if a participant does not pay attention to a certain cognitive process. For instance, highly automated cognitive processes may not be easily verbalized because the automated cognitive process can take place at a very low focal attention level or without any attention to recognizing the cognitive process.

Similarly, the stimulated recall verbal report may yield the same limitation since it is also based on the same rationale of collecting information from participants’ verbalization of their cognitive process. For this limitation of collecting only verbalized
information, the result of this study may not represent the recursive and dynamic nature of cognitive process. Second, using grounded theory as a research framework for the analysis can yield another potential lack of generalizability of this study. Grounded theory is a methodology for developing a theory that is grounded in data systematically gathered and analyzed. Although grounded theory can comprehensively help researchers build new theories, the result of analyzing the data may not be easily applicable to the practice of extending the findings because the result of grounded theory is very context-bound (Goetze, 1999).

The second issue to consider is a possible lack of reliability by using the unique sample. For the qualitative study, reliability depends, to a great extent, on the methodological skill, sensitivity, and integrity of the researcher. This study established the iterative model saturation process to enable me to have more sensitivity and to integrate the findings from the consecutive stages. In the evolutionary process of this study through the Model Initiation Stage and Model Elaboration Stage, the methodological elaboration has been strongly established. Nevertheless, the methodological elaboration, the sample used in this study, may cause a comparative lack of reliability of interpreting the findings. Since the participants of this study was limited to Korean students majoring in the instructional systems program, the participants may be a unique sample with respect to domain specific knowledge (major in Instructional Systems) and cultural background (Korean). Because of their major, their thinking process and performance for the given task can possibly be biased. All of the participants were familiar with how to design an instructional material. Thus, during their verbal reporting process, participants possibly used particular terms used in the field of instructional systems. Since this study used verbal reporting as one of major data resources, participants’ reports might have considerable impacts on my interpretation.

The third issue to consider is that this study may have low ecological validity in applying the result of this study to a real world situation. Since this study only focuses on the cognition of the individual of knowledge transformation in authoring hypertext, social and cultural interaction is intentionally excluded. However, authoring a hypertext
document requires various types of social and cultural interaction. Learners in the real world may use an authoring tool to make a hypertext document with their peers. Teachers may apply the idea of learning by authoring hypertext in the dynamic classroom context where learners may have interactions with their peers. Recently, studies in writing process are attempting to include the aspect of social interaction. As Zimmerman (1998) insisted, “writing is an active constructive process where cognition is embedded within social and cultural contexts, rhetorical constraints, and the act of discourse” (p. 30). In considering the similarities between the authoring and writing process, it would be legitimate to include the social and cultural interactions in a cognitive model of knowledge transformation as well. Thus, the social and cultural aspects still remain as unexplained as the result of this study.
APPENDIX A

LIST OF CONCEPTS OF AUSUBEL’S LEARNING AND INSTRUCTIONAL THEORY
List of Concepts of Ausubel’s Learning and Instructional Theory

**Anchoring Ideas:** Anchoring ideas are the specific, relevant ideas in the learner’s cognitive structure that provide the entry points for new information to be connected. They are what enable the learner to construct meaning from new information to the learner’s cognitive structure and experiences that are only potentionally meaningful.

**Assimilation Theory:** Assimilation theory is to describe the meaningful learning processes of subsumption, superordinate learning, and combinatorial learning. The result of the interaction that takes place between the new material to be learned and the existing cognitive structure is an assimilation of old and new meanings to form a more highly differentiated cognitive structure.

**Cognitive Structure:** Cognitive structure is the learner’s overall memorial structure or integrated body of knowledge. This cognitive structure is made up of sets of ideas that are organized hierarchically. Within any given hierarchy, the most inclusive ideas in the cognitive structure are the strongest and most stable.

**Discovery Learning:** Discovery learning is to have learners rearrange a given array of information, integrate it with existing cognitive structure, and reorganize or transform the integrated combination in such a way as to create a desired end product or discover a missing means-end relationship. The discovered content is internalized just as in reception learning.

**Influence of Knowledge Structure:** The organization of knowledge influences subsequent learning. If cognitive structure is clear, stable, and suitably organized, accurate and unambiguous meanings emerge and tend to retain their availability. If it is
unstable, ambiguous, disorganized, or chaotically organized, it tends to inhibit meaningful learning and retention.

**Learning Material:** Learning material must be potentially meaningful. It should be organized, readable, and relevant, so that learners do not fail to achieve the learning task. Learner must employ a meaningful learning set to any learning task. If the learner intends to memorize, then meaningful learning will not result.

**Meaningful Learning:** Meaningful learning is what learners already know and how that knowledge relates to what they are asked learn. Also it refers to the process of relating potentially meaningful information to what the learner already knows in a nonarbitrary and substantive way. With the prior knowledge, the learners can construct an understanding.

**Prerequisites of Meaningful Learning:** Cognitive structure and specific anchoring ideas within the cognitive structure are prerequisites to meaningful learning. They describe the memory structure within which new knowledge will be integrated. But we have yet to see how the new knowledge is actually connected with and incorporated into the learner’s existing knowledge.

**Readiness:** Readiness depends upon both the substantive content in the learner's cognitive structure and its organizational properties. Experts in a subject matter simply have a lot more extant knowledge than do novices in the subject. The idea that extensive background knowledge facilitates subsequent learning has been consistently demonstrated.

**Reception Learning:** Reception learning is that the entire content is presented to the learner in its final form. It commonly occurs in expository instruction, where learners
are told information rather than discovering it for themselves. The learner is therefore required to internalize the information in an available form for later use.

**Retention:** Retention involves maintaining the availability of acquired information so that it may be accessed for use at a later time. If new information is presented with immediately following meaningful learning, it will be easily accessible because of its stability anchored to the relevant concepts in the cognitive structure.

**Rote Learning:** Rote learning is a verbatim memorization that there is no real connection between what was already known and what was memorized. What was memorized is an arbitrary piece of information in isolation from the rest of cognitive structure. Either rote or meaningful learning can occur in reception and discovery learning.

**Understanding:** Students may attempt to memorize knowledge instead of understanding what it is. Likewise, in reception learning, just because the learner is in a position of receiving information does not mean the learner must be passive. Quite the contrary, meaningful reception learning implies that the learner is cognitively active.
APPENDIX B

SCREEN CAPTURES OF THE KNOWLEDGE ORGANIZER
Figure B-1. Cover Screen

Figure B-2. Introduction Screen of the Overview of this Study
**Procedure**

In this study, you will be asked to perform several tasks listed in the following numbers.

1. Read an instruction of how to perform a stimulated recall.
2. Read an instruction of how to use a computer application used in this study.
3. Rate a rubric scale to measure your familiarity of the content.
4. Reorganize the concepts to develop a learning material for your peer.
5. Draw a concept map of the content.
6. Perform a stimulated recall verbal report.
7. Take an open-ended interview with the researcher.

**Figure B-3. Introduction Screen of the Procedure**

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**Stimulated Recall Verbal Report**

During working on a given task, all your interaction with computer and gesture/behavior will be videotaped. After developing a learning material, a videotape containing your behavior will be shown to you.

In a meantime of watching the videotape, you need to verbally explain what you were thinking and/or why you showed some behaviors. The videotape plays a role to stimulate your memory to recall your cognitive process. That is the reason why it is called as a stimulated recall method. During watching the videotape, you can pause and stop it to provide more enriched explanation. Your stimulated recall process will also be videotaped.

**Figure B-4. Introduction Screen of the Stimulated Recall Verbal Report**

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Figure B-5. Introduction of Instrument

Figure B-6. Instrument Item #1
Figure B-7. Instrument Item #2

Figure B-8. Instrument Item #3
**Figure B-9.** Instrument Item #4

**Figure B-10.** Instrument Item #5
**Learning Material**

The material to be learned must be potentially meaningful. It should be organized, readable, and relevant, so that learners do not fail to learn because they can make no sense of the learning task. Learners must employ meaningful learning set to any learning task. If the learner intends to memorize, then meaningful learning will not result.

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**Meaningful Learning**

Meaningful learning is what learners already know and how that knowledge relates to what they are asked to learn. Also it refers to the process of relating potentially meaningful information to what the learner already knows in a nonarbitrary and substantive way. With the prior knowledge, the learners can construct an understanding.

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Figure B-11. Instrument Item #6

Figure B-12. Instrument Item #7
**Prerequisites of Meaningful Learning**

Cognitive structure and specific anchoring ideas within the cognitive structure are prerequisites of meaningful learning. They describe the memory structure within which new knowledge will be integrated. But we have yet to see how the new knowledge is actually connected with and incorporated into the learner’s existing knowledge.

**Readiness**

Readiness depends upon both the substantive content in the learner’s cognitive structure and its organizational properties. Experts in a subject matter simply have a lot more extant knowledge than do novices in the subject. The idea that extensive background knowledge facilitates subsequent learning has been consistently demonstrated.
Figure B-15. Instrument Item #10

**Scale of Familiarity and Understanding**

**Reception Learning**

Reception learning is that the entire learning content is presented to the learner in its final form. It commonly occurs in expository instruction, where learners are told information rather than discovering it for themselves. The learner is therefore required to internalize the information in a form that will be available for later use.

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Figure B-16. Instrument Item #11

**Scale of Familiarity and Understanding**

**Retention**

Retention involves maintaining the availability of acquired information so that it may be accessed for use at a later time. Immediately following initial meaningful learning, new information is easily accessible, its stability enhanced by virtue of its anchorage to relevant concepts in the cognitive structure.

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**Rote Learning**

Rote learning is a verbatim memorization that there is no real connection between what was already known and what was memorized. What was memorized is as an arbitrary piece of information in isolation from the rest of the cognitive structure. It is important that either rote or meaningful learning can occur in reception and discovery learning.

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**Figure B-17, Instrument Item #12**

**Understanding**

Students may attempt to memorize knowledge instead of understanding what it is. Likewise, in reception learning, just because the learner is in a position of receiving information does not mean the learner must be passive. Quite the contrary, meaningful reception learning implies that the learner is cognitively active.

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**Figure B-18, Instrument Item #13**
Problem Statement

The concepts in the previous session are Ausubel's learning and instructional theory. Now, you are going to reorganize the concepts to teach graduate students.

The purpose of this task is to develop a learning material for students. Supposingly the students are first year master students who want to take a class of learning and instructional theory. Also they do NOT have prior knowledge of Ausubel's theory. In other words, they are NOVICE of the concepts you have read in the previous session. Therefore, the learning material you will be developing should be appropriate for their knowledge status. Please reorganize the concepts as you think it can be the most appropriately effective to teach the students.

You will follow three steps for this session. First, you will be asked to select several concepts as chapter headings of your learning material. In this step you do not need to think about how the chapters should be sequenced. For the second step, you will have to make an appropriate sequence of the chapters. For the third step, you will link concepts to the chapters. More detailed information will be displayed in the following screens.

If you are ready to go, click the BLUE button.

Figure B-19. Problem Statement of the Task

Selection of Chapters

Please select concept(s) from List of Concepts and click the add button to move them into Chapters. You can select multiple concepts from List of Concepts as your chapters. If you click a concept of List of Concepts, the concept's content will be displayed in Content Viewer. You do NOT need to worry about the sequence of the chapters right now. You will rearrange the chapter in the next screen. When you finish, click the BLUE button.

List of Concepts
- Anchoring Ideas
- Cognitive Structure
- Discovery Learning
- Influence of Knowledge Structure
- Learning Material
- Meaningful Learning
- Prerequisite of Meaningful Learn
- Readiness
- Reception Learning
- Retention
- Rote Learning
- Understanding

Content Viewer
In discovery learning learners are required to "reread a given array of information, integrated it with existing cognitive structure, and reorganize or transform the integrated combination in such a way as to create a desired end product or discover a missing means-end relationship. After this phase is completed, the discovered content is internalized just as in reception learning."

Chapters
- Assimilation Theory

Add
Drop

Figure B-20. Selecting Chapters
Figure B-21. Sequencing the Chapters

Figure B-22. Linking Sub-concepts to the Chapters
APPENDIX C

EXAMPLE SCREENS OF PRODUCT OF KNOWLEDGE ORGANIZER
**Assimilation Theory**

Assimilation theory is to describe the meaningful learning processes of subsumption, superordinate learning, and combinatorial learning. The result of the interaction that takes place between the new material to be learned and the existing cognitive structure is an assimilation of old and new meanings to form a more highly differentiated cognitive structure.

**Discovery Learning**

In discovery learning learners are required to "rearrange a given array of information, integrate it with existing cognitive structure, and reorganize or transform the integrated combination in such a way as to create a desired end product or discover a missing means-end relationship. After this phase is completed, the discovered content is internalized just as in reception learning."

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**Figure C-1.** Linking Sub-concepts to the Chapters

**Figure C-2.** Linking Sub-concepts to the Chapters

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Meaningful Learning

Meaningful learning is what learners already know and how that knowledge relates to what they are asked to learn. Existing cognitive structure, that is, an individual's organization, stability, and clarity of knowledge is the principal factor influencing the learning and retention of meaningful new material.

Figure C-3. Linking Sub-concepts to the Chapters
APPENDIX D

SCREEN CAPTURES OF THE CONCEPT MAP BUILDER
Now you will be asked to make a concept map of the concepts of Ausubel's learning and instructional theory. The purpose of this session is to ask you to draw your knowledge structure of the concepts. In other words, it is to know how the concepts are interrelated in your mind. When you perform this session, please do NOT think about the learning material to teach the concepts to graduate students.

In this session all 13 concepts will be displayed as small text boxes. By using your mouse, you can move them to any place as you want. Once you move the concepts, you need to draw a line to indicate how they are linked.

To draw a line between two text boxes, double click on the one text box as your starting point, and then double click on the other text box as your destination of a line. Then, this program will draw a line between two text boxes. If you want to remove any line, place a mouse cursor on the line and click the righthand of mouse. Also, if you want to restart making a concept map, you can do it by clicking the RESET button.

Figure D-1. Instruction of the Concept Map Builder

The following is an example illustrating how a set of concepts can be linked.

Figure D-2. Example of a Concept Map
Figure D-3. Linking Sub-concepts to the Chapters

Figure D-4. Linking Sub-concepts to the Chapters
APPENDIX E

INSTRUCTION, GUIDELINES, AND PROMPTING QUESTIONS FOR THE STIMULATED RECALL VERBAL REPORT
Instruction for the Researcher

**Before viewing the videotape, Researcher says:**

Now we are going to watch this videotape. It records what you were doing to complete the tasks with the Knowledge Organizer and Concept Map Builder. I am interested in what you were thinking at the time you were performing the tasks.

You will see and hear what you were doing by looking at and listening to this videotape. When the video starts playing, please tell me what you were thinking, what was in your mind at that time.

I am going to put this remote controller on the table so you can use it to pause the videotape. When you watch the videotape, you can pause the video at any time you would like to do. So if you want to tell me something about what you were thinking, please pause the videotape first, and then proceed your verbal report. If I have a question about what you were thinking, then I will pause the videotape and ask you to talk about the screen.
Guidelines of the Stimulate Recall Verbal Report for the Researcher

1. Do not give a concrete reaction to participants.
2. If there is more than 40 sec to 1 min pauses, provide a prompting question to a participant to activate his/her verbal report.
3. Have a participant keep talking

Examples of Prompting Question

1. What were you thinking here?
2. Can you tell me what you were thinking at that point?
3. I see you are looking at the screen.
APPENDIX F

INSTRUCTION AND QUESTIONS OF INTERVIEW
INSTRUCTION AND QUESTIONS FOR THE SELF-DESCRIPTION

Before interviewing, the researcher says:

Now I'm going to ask you a couple of questions for the self-description of the Knowledge Organizer and Concept Map Builder.

(Showing the screens of the Knowledge Organizer and Concept Map Builder)

For the Knowledge Organizer

- Could you describe why the concepts were grouped in this screen?

For the Concept Map Builder

- Could you explain what you were considering when you were drawing the concept map?

Before interviewing, the researcher says:

Thanks for your descriptions and explanations! Now I would like to ask several open-ended questions.

- “If you were not familiar with the concepts, what would be the most difficult things for you to organize them?” (For content knowledge)
- “If your students were not novice, unlike described in the problem statement of the Knowledge Organizer, would the numbers of chunks you made be different?” (For authoring goal of the causal conditions)
- “If you have to use PowerPoint to make the learning material for your students, how it would be different from the Knowledge Organizer?” (For authoring tool of the causal conditions)
- Why the sizes of chunks are different? (For the size of chunks if they were grouped into different sizes)
Why did you put this concept [a firstly ordered chunk] in a first place instead of a second order? (For the sequence of chunks)
APPENDIX G

COPYRIGHT PERMISSION
Dear Dr. Marcy P. Driscoll:

I am completing a dissertation at Florida State University entitled “A Cognitive Model of Knowledge Transformation in Authoring Hypertext.” I would like your permission to reprint in my dissertation the text of the following pages of your book:


The requested permission extends to any future revisions and editions of my dissertation, including non-exclusive world rights in all languages. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. This authorization is extended to University Microfilms International, Ann Arbor, Michigan, for the purpose of reproducing and distributing copies of this dissertation. Your signing of this letter will also confirm that you own the copyright to the above-described material. If these arrangements meet with your approval, please sign this letter where indicated below and return it to me. Thank you very much.

Sincerely,
Jeeheon Ryu

PERMISSION GRANTED FOR THE
USE REQUESTED ABOVE:

Marcy P. Driscoll

Date: 5/14/04
APPENDIX H

HUMAN SUBJECTS COMMITTEE APPROVAL
Office of the Vice President For Research  
Human Subjects Committee  
Tallahassee, Florida 32306-2763  
(850) 644-8633  FAX (850) 644-4392

REAPPROVAL MEMORANDUM

Date: 2/10/2004

To: Jeeheon Ryu  
1951 N. Meridian Road #85  
Tallahassee, FL 32303

Dept.: Educational Psychology & Learning Systems

From: John Tomkowiak, Chair

Re: Reapproval of Use of Human subjects in Research:  
A Cognitive Model of Knowledge Transformation

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 1/8/2005 please request renewed approval.

You are reminded that a change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must report to the Chair promptly, and in writing, any unanticipated problems involving risks to subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols of such investigations as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Robert Morgan  
HSC No. 2004.006-R
APPENDIX I

INFORMED CONSENT FORM
Dear Participants,

Jeeheon Ryu, a doctoral student of the Department of Educational Psychology and Learning Systems, requests your participation in his dissertation study at FSU entitled “A Cognitive Model of Knowledge Transformation”.

The purpose of this research is to investigate how students are using their cognitive strategies to externalize their knowledge through a computer program. The activities for which data will be collected involve using a computer program and answering questions regarding your use of cognitive strategies. These activities are mainly about organizing your knowledge for learning and instructional theories. It will take approximately 60 minutes to complete the organization process. The activities will not affect your any academic achievement and/or grade. There are minimal risks if you agree to allow your data to be included. During your participation, you will be videotaped. The purpose of videotaping is to show you the videotape to recall your cognitive process. It will take approximately 30 minutes for recalling your cognitive process. Thus, the entire data collection process may take approximately 90 minutes.

Jeeheon Ryu will do the following to keep confidentiality of your records: All data including your identification, video tapes, and paper work will be stored in a locked cabinet at the researcher’s home. They will be destroyed by December 31, 2004. The results of this research study may be published but your name or identity will not be revealed.

Jeeheon Ryu will answer any questions from you through phone, face-to-face, and/or email. You can contact with the researcher at 850-297-1123 or jjr7148@garnet.acns.fsu.edu. You may withdraw your consent and discontinue participation at any time. In signing this consent form, you are not waving any legal claims, rights or remedies. A copy of this consent form will be offered to you.

By signing this form, I have read and understand that I will be videotaped by the researcher. These tapes will be kept by the researcher in a locked filing cabinet. Also, I understand that only the researcher will have access to these tapes and that will be destroyed by December 31, 2004.

Participant’ Signature:___________________                     Date:________
REFERENCES


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Maor, D., & Knibb, K. (1999, November). *Video analysis: A Qualitative tool for investigating students' learning in a constructivist-oriented multimedia in a*
science classroom. Paper presented at the the Australian Association for Research in Education, Melbourne, Australia.


BIOGRAPHICAL SKETCH

Jeeheon Ryu was born on February 19, 1969 in Seoul, Korea. He was graduated from Bae-Myung High School in 1987. He received the Bachelor of Arts with a major in Education at Korea University in Seoul, Korea. After the graduation, he entered a graduate school of education and earned his masters degree in Educational Psychology at Korea University in 1994.

After completing his masters degree, he had served in the Korea Military Academy as a faculty member of the Department of Psychology as a first Lieutenant. In 1997, he retired and started his doctoral program in Educational Psychology, Evaluation, and Methods at Korea University. He started his oversea study as a doctoral student majoring at the instructional technology in 1999 at the Utah State University. However, due to financial and family consideration, he moved to the Florida State University in 2000.

During his stay at FSU, his excellent and dynamic academic performances were recognized through the Ruby Diamond Future Professor Award in 2003, Gagne-Briggs Excellent International Student Award in 2002, Cochran Intern Award by Educational Communication Technology (ETC) foundations in 2002. He has been nominated as a finalist of the Gagne-Briggs Awards for Outstanding Doctoral Students from 2002, 2003, and 2004 and Outstanding Service in 2002. His dissertation study was supported by the Florida State University Dissertation Grant. He also published and presented his academic works at professional conferences and academic journals during his study at the Florida State University. He earned a minor in measurement and statistics.

He is interested in the development of Learning and Instructional Theory in multimedia learning environment, use of Computer As an Cognitive Tool,
implementation of Emerging Technologies for pedagogical purposes, and development of Research Methodology of Qualitative and Quantitative Approach in Education.