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THE EFFECTS OF CONCEPTUAL MODEL PROVISION AND COGNITIVE STYLE ON PROBLEM SOLVING PERFORMANCE OF LEARNERS ENGAGED IN AN EXPLORATORY LEARNING ENVIRONMENT

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A Dissertation APPROVED FOR THE
DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

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ABSTRACT

The primary purpose of this study was to investigate the effects of conceptual model provision and a cognitive style characteristic (i.e., field-dependence/field independence) on problem-solving performance in an exploratory learning environment. A second issue investigated was the role of individual differences, more specifically cognitive style, in mental model development and problem solving in an exploratory learning environment. In addition, this study investigated what effects prior knowledge, prior experience with photography, computer playfulness, and interest in photography have on problem solving of FD/FI learners.

Sixty-one undergraduate students participated in the study. The Group Embedded Figures Tests was used to classify subjects as field dependent or field independent learners. The design of the study was a pretest/posttest control group design. Two independent variables were employed in this study: (a) conceptual model provision/nonconceptual model provision and (b) cognitive style characteristic (i.e., FD/FI). The dependent variables were: (a) posttest scores, (b) length of engagement with instructional materials. Data were analyzed using several statistical analyses: *t*-tests, univariate analysis of variance, and stepwise multiple regression analyses.

The results of the study revealed no significant main effect of conceptual model provision and no interaction effect of conceptual model provision and cognitive style characteristic (FD/FI) using scores from Posttest 1 and Posttest 2. FD/FI was found to be statistically significant on Posttest 1. FI subjects performed significantly better than FD subjects. The results also revealed no significant main or interaction effect for

conceptual model provision and cognitive style characteristic on length of engagement with photography simulation. Exploratory data analysis showed that Pretest performance were significantly correlated with Posttest 2 performance and that gain scores were significantly correlated with performance on both the Pretest and GEFT. From the results, the researcher concluded that conceptual model provision did not prove to be statistically significant; however, the cognitive style characteristic of FD/FI was statistically significant in terms of performance on Posttest 1. FI subjects performed better in the exploratory learning environment than did FD subjects on Posttest 1 and Posttest 2. FI subjects also spent more time engaging with the highly exploratory photography simulation. Due to the lack of significant findings for conceptual model provision and length of engagement with the photography simulation, more empirical research is suggested.

CHAPTER 1

INTRODUCTION

Are discovery learning environments more effective than expository learning environments? Is learner-controlled instruction more effective than "program-" or teacher-controlled instruction? Is "heavily-cued" text more effective than "lightly-cued" text? These questions have been the focus of much research in the past decade. Much of this research seems to indicate that no particular instructional strategy is necessarily better than another (Cronbach, 1967; Darwazeh, 1994; Salomon, 1972; Smith, 1992; Snow 1977; Tobias, 1976), but there are other contributing factors, such as learner, task, and contextual variables that must be considered when designing learning environments (Darwazeh, 1994; Smith, 1992).

With increasing capabilities of instructional technology, these questions become even more critical. Highly interactive technologies are changing the way instruction and training are delivered. For example, the traditional classroom setting has the potential to be transformed into computer-based, exploratory learning environments that reflect the basic assumption that learner motivation, performance, and productivity can be enhanced by interactivity (Jih & Reeves, 1992). Several scholars (Hannafin ,1992; Jonassen, 1986; Lajoie, 1993; Rieber, 1996; Wilson, 1995) agree that computer-based, exploratory learning environments can provide interactive activities that facilitate "student-centered" learning. In "student-centered" learning environments, the student determines "what, when, and how learning will occur" (Hannafin, 1992, p. 54). One basic assumption is that "student-centered" learning environments support cognitive processing (e.g., accessing existing conceptual links and building new ones), as well as provide guidance and support for the learner in terms of problem solving and decision making.

Within this particular literature on exploratory learning environments, there also appears to be a tremendous move toward focusing on learning in the context of problem-solving activities. To solve problems in a complex domain, learners must be able to select and apply the most appropriate concepts, principles, and procedures that are prerequisite to problem solving. Experts are usually able to make the most appropriate selections; on the other hand, novices tend to find this process rather difficult (Gott, Lajoie, & Lesgold, 1991). These same authors believed that performance differences in problem-solving skills of experts and novices can possibly be attributed to differences in abilities to organize knowledge and build appropriate mental models. Some of the research on mental model development (Bromage and Mayer, 1981; Glaser, 1984; Gagné & Glaser, 1987) seems to support the notion that providing learners with a conceptual model of the problem space and structure (*conceptual model provision*) can facilitate the development of an appropriate mental model. Also, differences in problem solving abilities of learners can be attributed to an individual's cognitive learning style (e.g., field dependence/field and independence) (Green, 1985). This study sought to add empirical research to this field of study by examining the effects of conceptual model provision and cognitive style characteristic on problem-solving performance in an exploratory learning environment created by a photography computer-based simulation.

Purpose of the Study

Numerous scholars (Darwazeh, 1994; Salomon, 1972; Smith, 1992; Snow & Lohman, 1984; Tobias, 1976) suggested that the degree of instructional support (e.g., minimal or maximal) given to learners should be based on a variety of learning variables such as, learner characteristic, task, and context. For example, an individual who lacks the domain-specific learning task strategies needed to successfully complete a complex learning task may be assigned to an instructional treatment with maximal instructional support, where as, his/her counterpart, who possesses these strategies, may be assigned to an instructional treatment with minimal instructional support.

The primary purpose of this study was to investigate the effects of conceptual model provision and cognitive style characteristic (i.e., field dependence/field independence) on problem-solving performance in an exploratory learning environment. Also, this study investigated the interactive effects of conceptual model provision and the cognitive style characteristic of field dependence/field independence on problem-solving performance and on length of time learners engage with instructional materials in an exploratory learning environment. A secondary research question was: Do any of the following learner variables interact with the conceptual model and FD/FI variable: prior knowledge, photography experience, computer playfulness, and interest in photography, yielding differential effects of presence/absence of a conceptual model on learning performance?

Background

Exploratory learning environments are viewed as highly interactive learning systems that allow students to construct their own representations of knowledge and test the adequacy of their mental models. Exploratory microworlds and computer-based simulations are two examples of this type of learning environment. In exploratory learning environments, learners have the responsibility of selecting and using the appropriate principles, procedures, and strategies to solve problems. The large number of instructional options available to the learner in exploratory learning environments may present problems for some learners. For example, system users whose prior knowledge and computer experience is limited, may: (1) experience problems in navigation and become disoriented (Jih & Reeves, 1992; Kenny, 1993; Rezabek & Ragan, 1989) and (2) feel overwhelmed by the different options available leading to more mental effort and increased cognitive load (Jih & Reeves, 1992; Jonassen, 1989; Kenny, 1993). How can instructional designers help learners engaged in exploratory learning environments overcome these problems? One possible solution might be to provide differential instructional support/guidance (e. g., scaffolding, orienting, prompting, providing feedback) to learners with varying styles and abilities.

Providing differential instructional support/guidance to learners is not a new concept. Scholars such as Cronbach (1967), Salomon (1972), Snow (1977), and Tobias (1976) have supported the idea of adapting instruction to accommodate the individual learners' needs—Aptitude Treatment Interaction (ATI)—for several decades. These scholars believed that learning can be maximized by providing differential instructional treatments based on certain learner aptitudes. The following section will discuss the use of adaptive instructional models as prescriptive tools for providing differential instructional support/guidance.

Providing Differential Instructional Support/Guidance. Recently, the question that often intrigues researchers is: What kind and/or level of instructional support or guidance is needed to facilitate learning based on learner characteristics, subject-matter content, learning tasks, instructional strategies, and certain types of learning contexts? Smith (1992) presented an instructional model designed to identify various relationships that exist among domain-specific problem-solving tasks, learner characteristics, and context variables (i.e., instructional setting) as supported by supplantive and generative instructional situations. This model is referred to as the COGSS (Choice of Generative/Supportive Strategies) model. The purpose of Smith's (1992) model was to provide a theoretical framework regarding the advantages and disadvantages of supportive and generative instructional strategies. Smith (1992) believed that when designing instruction, attention should be given to matching instructional strategies to a particular instructional situation rather than trying to unilaterally choose between a structured and/or exploratory (highly unstructured) learning environments.

Along this same line of thought, Darwazeh (1994) suggested examining the interaction of instructional variables such as, learner characteristics, content characteristics, and level of learning and their relationship to the different cognitive learning strategies, generative and embedded. From an extensive review of experimental and theoretical studies conducted from the 1960s to 1990s on cognitive-strategy activators, Darwazeh (1994) proposed two instructional design models: one for embedded cognitive activators and the other model for generative cognitive activators. These adaptive models were developed to: (a) provide a theoretical framework for designing instruction with a consideration of cognitive-strategy activators and (b) guide learners on how to develop effective learning strategies.

Smith (1992) and Darwazeh (1994) share similar views in that they both suggest the use of adaptive models for the designing of instruction for certain types of learning situations. Both models prescribe the degree of cognitive processing support needed (i.e., generative vs. supplantive/embedded strategies) based on in certain learning conditions. They propose that learners differ in terms of their need for instructional support and guidance. However, differences in achievement can be reduced by providing instructional support to accommodate or complement the individual learners' needs (Whitener, 1989). Whitener (1989) suggested that higher levels of instructional support tend to cause greater differences in the performance of high- and low-aptitude individuals. More specifically, he argued that "the provision of higher support will increase the performance of low-aptitude individuals to some extent, but will increase the performance of high-aptitude individuals to a greater extent, because they have the capabilities or knowledge to capitalize on and benefit form the support" (p. 69).

Njoo and de Jong (1993) considered learner control to be a critical element to exploratory learning. These scholars argued that instructional support measures should be designed to "leave as much freedom to the learner as possible" (p. 822). Njoo & de Jong's views on instructional support provision are similar to those of Smith (1992) and

Darwazeh (1994) in that they believed adequate of instructional support falls on a continuum somewhere between "obligatory" measures (i.e., embedded strategies) or "nonobligatory" measures (generative strategies).

Although there have been a large number of studies investigating the interaction of learner characteristics with instructional support, more commonly referred to as Aptitude Treatment Interaction (ATI) research, there are many questions that still remain unanswered. For example, does conceptual model provision enhance the performance of all types of learners? The following section will briefly discuss research investigating the effectiveness of using conceptual models to provide instructional support.

Conceptual Model Provision. Previous research has led to varying opinions as to the effectiveness of conceptual model provision. Most of the research tends to support the notion that conceptual models can be effective tools for providing instructional support; however, there may be other learning variables that determine the degree of conceptual model effectiveness. For example, when the subject-matter domain, the learning task, or learning environment is complex, some learners, especially novice ones, may need help in knowledge representation and organization.

Bromage and Mayer (1981) studied the effects of conceptual model provision on creative problem-solving performance. Subjects were divided into two groups. Half of the subjects were provided with a conceptual model; half were not. The conceptual model used in this study is what Bromage and Mayer called a "concrete mechanical model." The conceptual model provided students with an explanation of the operations of a camera, with verbal and pictorial analogies. The results of their study showed similar performance from both groups on recall and application of basic information; however, the conceptual model group did perform significantly better than the control group on creative problem solving. Those participants who were provided with information concerning the underlying mechanisms of the camera performed better on far transfer problems, such as identifying the cause of a specific outcome and determining which variables were relevant in novel situations.

Not only has previous research focused on the effectiveness of conceptual model provision on mental model development and problem-solving performance, but also it has focused on the impact of individual differences on learning. Sein and Bostrom (1989) examined the effects of conceptual model provision and individual differences (i.e., visual ability and learning mode) on learning to operate an electronic filing system. The participants were given one of two types of conceptual models—abstract or analogical. The study showed that subjects who scored higher in terms of their abilities to construct a mental model of a target system and use it (high visuals) scored significantly better than their counterparts (low visuals) indicating that conceptual model provision can possibly improve learner performance when conducive to certain learner characteristics. Based on their study (Sein & Bostrom, 1989) and previous studies, they concluded that the effectiveness of a conceptual model depends on the individual user characteristics interacting with the conceptual model, not on the type of conceptual model. One possible drawback to this study was that no mental model assessment of the participants was conducted prior to the instructional treatment; therefore, the question arises as to how mental model development/improvement was accurately assessed.

Koubek (1990) conducted a study to examine the effects of conceptual model provision, mental model development, and cognitive style (i.e., field dependence/field independence) on simple and complex tasks. Two different conceptual models were used as instructional treatments—alphabetical arrangement and hierarchical arrangement of Microsoft Word commands. The participants' mental models were assessed after conceptual model provision (i.e., Initial Performance) and once again after being allowed to practice "automated" and "controlled" tasks (i.e., Final Performance). Although there were no main effects found for conceptual model provision and cognitive style, the results of the study showed the following significant interactions: (a) field dependent (FD) subjects given the "hierarchical" conceptual model performed significantly better ($p < .05$) on the initial performance than any of the other treatment groups, (b) FD subjects, given the "alphabetical" conceptual model, scored significantly better ($p < .05$) than FI subjects in terms of learning rate—completion of task in the designated time, and (c) task representation was a significant determinant of performance on complex tasks. According to Koubek (1990), to maximize learning performance, "emphasis should be placed on selecting and reinforcing the correct representation for the particular task requirements and individual operator characteristics" (p. 18).

There have been numerous studies on how individual differences in aptitude and the degree of instructional support can predict learner response to certain forms of instruction. This study sought to examine the relationship of conceptual model provision and cognitive style dimension as a means of determining the degree of instructional support needed for problem-solving tasks in exploratory learning environments.

Definition of Terms

Mental Model—a mental representation of knowledge resulting from interaction with the environment that drives an individual's performance.

Conceptual Model—instructional support device (developed by teachers, instructional designers, scientists, or engineers) used to help learners build or modify mental representations of a target system (e.g., equipment, software, tasks, etc.).

Exploratory Learning Environment—a computer-based learning environment that allows users to explore the subject matter content and activities of a system according to their own needs and interests.

Cognitive Style—individual variations in abilities to perceive, organize, process, remember and utilize information while interacting with the environment.

Field Dependence/Field Independence—a cognitive style characteristic that describes the degree to which an individual perceives and comprehends information, globally and analytically; learners who see objects in their field of view as a single unit are classified as "field dependent," and learners who see objects in their field of view as separate units are classified as "field independent."

Research Questions

This study examined the following questions:

1. Does conceptual model provision influence domain-specific problem solving?
2. Does conceptual model provision differentially affect problem-solving performance of field dependent versus field independent learners?

3. Does conceptual model provision and the cognitive style characteristic of FD/FI influence length of engagement with instructional material in an exploratory learning environment?

Significance of the Study

Learning outcomes are influenced by the use of various types of instructional strategies (Jonassen & Grabowski, 1993). Different learning outcomes require different cognitive processes, and therefore, different types of strategies (Gagné, 1985). These instructional strategies may be designed in such a way that they are more facilitative for some learners and less facilitative for others. For example, the high level of interactivity provided by some of the interactive learning systems may be appropriate for some learners and inappropriate for others (Jih & Reeves, 1992). Due to the potential of computer-based technology, more than ever educators and instructional designers are faced with the great challenge of designing learning environments that will support individual differences, as well as adapt instruction based on learning outcomes and instructional settings.

Learning theory research (Gagné & Glaser, 1987; Jih & Reeves, 1992; Mayer, 1989) suggests that one particular instructional strategy for helping individuals enhance learning performance is to help learners formulate an appropriate mental model by providing them with a conceptual model. A conceptual model can be described as a mental model that the expert (e.g., teacher, instructional designer, engineer) has created that represents the target system/device/task. For example, Sein and Bostrom (1989) used a picture of a filing cabinet as an analogical representation of the target system—an electronic mail filing system called VAX mail. The primary purpose of a conceptual model is to facilitate the acquisition, assimilation, and application of knowledge, thereby bringing about more effective learning (Driscoll, 1994; Norman, 1983).

According to Jih and Reeves (1992) and Jonassen (1993), one of the major concerns with hypertext-based or other exploratory learning environments is that some of the learners may have an inadequate mental model, also referred to as ill-developed schemas, that will inhibit learning. Highly exploratory learning environments provide lots of information but very little instructional support and guidance to learners. Learners with deficiencies in prior knowledge of the subject-matter domain, in prior experience with the target system and in necessary metacognitive skills may find it difficult to perform successfully in this type of learning environment. Therefore, a primary concern of instructional designers and teachers should be to develop learning systems and instructional material that will aid learners in developing more accurate and usable mental models.

Gaining knowledge on the impact conceptual model provision has on problem-solving performance in an exploratory learning environments and how conceptual model provision interacts with specific learner characteristics to influence learning, will help one determine the degree of support that learners require to accomplish certain types of learning tasks and perform successfully in certain types of learning environments.

CHAPTER 2

REVIEW OF THE LITERATURE

The primary objectives of this research study were: (a) to investigate the effects of conceptual model provision on problem solving performance in an exploratory learning environment, (b) to examine the potential interactive effects of conceptual model provision and cognitive style characteristic—field independence/field dependence—on problem-solving performance in an exploratory learning environment, and (c) to examine the potential interactive effects of conceptual model provision and cognitive style characteristic on length of time learner engages with instructional materials. The purpose of this chapter was to provide a theoretical and empirical framework for the consideration of conceptual model provision as an important variable in instructional design research.

First, theory and research related to exploratory learning environments are discussed, with special attention given to the use of computer-based simulations and the need for instructional support in the design of exploratory learning environments. Second, an overview of schema theory and mental model theory is presented with emphasis given to the development and assessment of mental models. Third, the impact of conceptual models on learning is discussed, with emphasis given to the use of conceptual models as instructional support devices. Finally, literature on the role of individual differences in learning is reviewed with special attention given to one particular cognitive style characteristic—field independence/field dependence.

Theory and Research on Designing Learning Environments

The emergence of new interactive technologies in recent years has brought about new challenges for instructional designers, as well as for teachers and learners. These new interactive technologies have the "capacity to present, manipulate, control, and manage educational activities" (Hannafin, 1992, p. 50). Using new interactive technologies to design of various types of learning environments and to examine the effects of different learning variables such as, cognitive style (e.g., field dependence/field independence, impulsive/reflective), learning tasks and outcomes (e.g., problem solving, transfer, use of metacognitive skills), instructional design approaches (e.g., generative versus supplantive strategies), and instructional delivery modes (e.g., web-based learning, interactive video) have on different learning environments. One such area of research is the design of exploratory learning environments.

Exploratory Learning Environments

Technology-based learning environments are one of many technological innovations that have emerged from interactive technologies. These learning environments use a variety of technologies (e.g., simulations, interactive videos, microworlds, CD-ROM, DVI, telecommunications, World Wide Web/Internet) to support learner-centered learning. For example, exploratory learning environments"—also referred to as open, discovery, generative, constructivist, hypermedia/hypertext, enriched, and interactive learning systems—allow learners to explore the content and activities of the system according to their own needs and interests (Hannafin, 1992; Jih & Reeves, 1992; Land & Hannafin, 1997; Reiber, 1992). "The role of instruction in such learning environments is to provide substantive support for student-initiated knowledge or skill development; not necessarily to provide a vehicle for knowledge transmission" (Hannafin, 1992, p. 54). In such learning environments, knowledge is acquired primarily by means of inquiry, scientific discovery, problem solving, and inductive reasoning (Land & Hannafin, 1997; Njoo & Jong, 1993).

The primary design feature of exploratory learning environments is "interactivity." Interactivity not only engages the system user in internal behaviors such as self-motivation and mental processing, but also external behaviors such as making choices, answering questions, and solving problems (Jih & Reeves, 1992). When making instructional design and implementation decisions, consideration should be given to the benefits and drawbacks of a particular kind of learning environment. Some of the predicted benefits of exploratory learning environments as identified from the literature are that they:

- incorporate a variety of instructional media, learning activities and resources in the same instructional program (Hannafin, 1992)
- support multi-content integration—cross topic linkage (Hannafin, 1992)
- support individual and group knowledge representation—collaborative learning, learning communities, social negotiation (Hannafin, 1992; Vosniadou, 1996)
- provide real-world context (Jonassen, 1993; Norton & Wiburg, 1998;Vosniadou, 1996)

- support creative and divergent thinking and situated learning (Norton & Wiburg, 1998)
- provide vehicle for conventional problem solving and authentic problem solving
- support greater cognitive flexibility and the presentation of multiple perspectives that other types of media do not offer (Jonassen, 1993; Vosniadou, 1996)
- promote use of metacognitive skills (Hannafin, 1992; Jonassen, 1993; Vosniadou, 1996)
- help learners refine their understanding of concepts—support conceptual development/representational growth—(Hannafin, 1992; Jonassen, 1993; Land & Hannafin, 1997; Vosniadou, 1996).

Collins (1996) offered several other design considerations for learning environments, computer-based or not. He divided these design considerations into four different categories: (a) learning goals (e.g., whole task vs component skills), (b) learning context (e.g., learner control vs computer or teacher control), (c) learning sequences (e.g., structured vs unstructured), and (d) teaching methods (e.g., scaffolding). He proposed the use of a cost-benefits approach to evaluating the each design issue/tradeoff. "The costs and benefits relates to the effects on student learning and motivation, and to the costs in terms of time, money and effort required to implement any aspect of a learning environment" (Collins, 1996, p. 347). Using a cost-benefits approach to evaluate design issues should result in more efficient and effective learning environments. These considerations are especially critical in exploratory learning environments.

Exploratory learning environments have some design and implementation drawbacks as well. Predicted drawbacks generated from the literature are that exploratory learning systems:

- May not provide the instructional support needed for learners who still rely on or prefer externally directed methods of learning (Land & Hannafin, 1997,1998).
- May not be able to adapt to the unanticipated implementation requirements of teachers (Land & Hannafin, 1998).
- May lack a theory base for selected approaches, methods, or desired outcomes (Land & Hannafin, 1998).

In addition, a few system user considerations were also identified from the literature. Predicted drawbacks are that system users:

- May lack sufficient navigation skills and become disoriented and confused in a hypertext-based program, which may lead to more mental effort resulting in cognitive overload and frustrations, thereby inhibiting the learning process (Jih & Reeves, 1992; Smith, Ragan, McKay, & Rezabek, 1997)
- Are sometimes ill-equipped, that is, lack sufficient prior experience, prior knowledge, or metacognitive skills, to make appropriate choices (Hannafin, 1992; Jonassen, 1993; Smith, Ragan, McKay, & Rezabek, 1997; Wallace and Kupperman, 1997)

- May focus their attention on unimportant content or features of the program and fundamental knowledge and skills may not be learned (Hannafin, 1992)
- May rely on naïve beliefs rather than choosing other identified alternatives or generating new ones (Greene & Land, 2000; Land & Greene, 2000; Land & Hannafin, 1997).
- May not always use open systems in ways that support knowledge construction (Atkins & Blisset, 1992; Greene & Land, 2000; Land & Greene, 2000)

Jonassen (1993) addressed three other issues in terms of proposed implementation of "enriched" learning environments that are related to implementation, rather than system design:

- **Conflict between Teaching and Learning Styles**—"The attributes of enriched learning environments . . . stand in direct conflict with the methods that learners have been taught and held accountable to use. Knowledge construction usually accedes to reproduction. . . Teachers find it difficult to give up control to students, yet we know that acceding control is necessary for developing reflective, independent learners" (p. 37).
- **Use of Metacognitive Skills**—Learners may not employ metacognitive skills unless they are required of learners.
- **Poor Evaluation of Instruction**—Ways to effectively evaluate the learning outcomes of these enriched learning environments have not been fully established.

Bull and Cochran (1991) contrasted the role of computer-assisted instruction and learner-based tools/software. They argue that learner-based tools are open-ended and learner-centered, provide a context for discovery and exploration, and can be adapted to fit the student's learning style as well as the instructor's teaching style. Learner-based tools tend to focus on the learning process rather than the product, and this learning process is characterized by a three-way interaction—student, teacher, computer (Bull & Cochran, 1991).

Along these same lines of thought, Norton and Wiburg (1998) argue that some learning environments "are designed to capitalize on the technical possibilities of multimedia but do not consider pedagogical issues; they fail to create productive learning environments" (p. 261). Rather than focusing on the technology application, research should be focused toward the interaction of various technologies with variables such as, learner differences, learning tasks, learning outcomes, and learning contexts.

Bull and Cochran (1991) identified several attributes of learner-based tools. The argue that learner-based tools:

1. are extensive, permitting the user to create uses and applications of the tool that were not necessarily envisioned by the developer;
2. are characterized by a low threshold, which permits novices to begin developing interesting applications almost immediately;
3. are "high ceiling", permitting expert users to develop sophisticated applications (p. 50)

Wiburg (1995) identified some evaluation questions instructional designers should consider before designing learning environments:

1. What is the theoretical approach to learning that guides design of this learning environment? Is it behavioristic, presenting information in small pieces and containing reinforcement aimed only at the individual learner, or is the theoretical approach consistent with constructivist notions of learning, providing opportunities for students to investigate and interact with rich problems?

2. Does the learning environment support opportunities for groups of students to discuss and work with the material?

3. Is the learning environment well organized? Is it easy to navigate? Are there clear pathways to locating necessary information? If the learning environment has different parts, are the functions and uses of each part clear?

4. Are there a variety of ways to use the learning environment, including an opportunity to make choices about the kinds and levels of learner control?

5. Are a variety of perspectives presented for the concepts taught? Are students encouraged to critically evaluate information regardless of whether the information is presented in images, sounds, or text?

6. Within the structure of the learning environment, are opportunities provided for students to construct their own links between different kinds of information? (p. 61)

If instructional designers would consider these questions prior to having learners engage in a traditional or contemporary learning environment, learning effectiveness might be improved. All too often, instructional design considerations are the last to be considered, if considered at all.

<u>Generative Learning and Hypermedia-Based Learning Environments</u>

Generative learning has been referred to as the learner's active participation in the generation of relationships and meanings (Volk and Ritchie, 1999). More specifically, generative learning activities, which are used to create generative learning environments, involve the restructuring or manipulation of information to generate organizational or integrated relationships and the constructing of personal meaning (Grabowski, 1996). Some examples of generative learning activities are creating concept maps, note taking, predicting outcomes, paraphrasing, diagramming, creating examples, and relating information to prior knowledge.

Generative learning consists of four processes that work together to facilitate learning: motivation, learning, knowledge creation, and generation; ignoring any one of these could cause the learner to take a more passive approach to learning (Grabowski, 1996). Therefore, learning environments should be designed to engage learners in active processing information.

Hypermedia-based learning environments offer promise in supporting generative learning activities. These environments can be designed to support higher-order thinking skills, such as, problem solving, self-regulation and evaluation, reflection, and goal setting.

Volk and Ritchie (1999) conducted a study to evaluate the impact of two generative learning strategies (i.e., concept maps and manipulation of objects) on the individual learner and cooperative learning groups. Eighty six grade science students participated in this study. They were randomly assigned to a group or individual condition. The researchers hypotheses were: (a) based on the notion that the manipulative activity completing a science experiment acts as a generative learning strategy, student who use this method will obtain criterion achievement scores equal to those students developing concept maps on the same topic and (b) students who work in teams will score significantly higher on criterion achievement tests than students who work individually.

Materials for the study included a chapter from a science textbook and a 13-item multiple choice test, which was administered at three different times during the study, one day after the study begin, 10 days after, and 32 days after. The four treatment groups were: (a) working with concept maps in a team, (b) working with concept maps individually, (c) working with manipulatives in a team, and (d) working with manipulative individually.

At the end of the first chapter segment, subjects in the concept maps treatment groups were asked to create concept maps that described the characteristics of minerals, the topic they had just studied. Subjects in the manipulative treatment groups were given a set of hardness points, a Moh's hardness scale table, a mineral color chart, and a set of six minerals and were asked to use the equipment to identify each mineral sample. At the conclusion of the chapter (10 days later), the subjects switched treatment group activities. The next day a chapter test (Test 2) was given using the same questions as the initial test given one day after the study begin (Test 1). Test 3 (delayed posttest) was given 32 days later.

There was no significant difference found among students who worked individually and those who worked in teams. However, an analysis of the interaction between strategies and organization revealed a statistically significant interaction between concepts/manipulatives and teams/individual on all three tests, $p < .10$. On Test 1, teams creating concept maps had a higher mean score ($M = 11.95$) than the manipulative teams

(M = 10.72). On Test 2, the manipulative teams had a higher mean score (M = 12.05) than teams creating concept maps (M = 11.11). The researchers concluded that the unusual findings might be attributed to parameters such as, pretest performance, general aptitude, or student learning style rather than the experimental treatment.

An a analysis of the data from Test 3 revealed a significant difference between mean scores of subjects working with concepts maps (M = 11.82) and subjects working with manipulatives (M = 11.11). The researcher concluded that having subjects create concept maps prior to engaging in manipulative activities could facilitate long-term retention. Volk and Ritchie (1999) argued that this finding supports Reigeluth's elaboration theory--the importance of explicitly stating the overall structure of the content before getting into details.

Possible limitations to this study as identified by the researchers were: (a) possible threats to external validity (i.e., multiple treatment interaction) and (b) there was a difference in the information presented between the test sessions.

The need for more empirical research in the areas of generative learning is still apparent. Additional research studies need to be conducted to examine the effects of various generative learning strategies (e.g., predicting outcomes) on individual difference factors (e.g., cognitive style), specific learning tasks (e.g., problem solving), and various learning environments (e.g., exploratory learning environment).

<u>Use of Simulations in the Design of Learning Environments</u>

Simulations have been used in education and training for many decades and have been applied to a number of different domains such as, math, science, social studies, business, government, and health care. Simulation can be defined as "an activity that attempts to mimic the most essential features of reality but allows learners to make decisions within the reality without actually suffering the consequences of their decisions" (Smith & Ragan, 1993, p. 255). They are usually classified into three different categories: role playing, games, and computer simulations (Taylor & Walford, 1978).

Computer simulations combine some of the characteristics of computer-assisted instruction and simulation techniques (Seidner, 1978). Generally, computer simulations offer the learner a choice of strategies to use in learning from them; however, the best strategy to use may not be always obvious. According to Seidner (1978), learning from simulation and games occurs when the learner actively interacts with the simulated environment through his/her own experiences to discover certain concepts or principles embedded in the simulation model. Studies comparing simulations/games with other teaching techniques suggest that "they are about as effective as other techniques for teaching cognitive skills, however, not necessarily any better (Seidner, 1978, p. 32). In addition, Seidner (1978) believed that Gagné's Events of Instruction, which appears to promote a linear instructional sequence, may be particularly useful as guidelines for more nonlinear simulations/games research. For example, empirical studies could be conducted to assess the effects of Gagné's instructional events on the performance of learners in computer-based, simulated learning environments.

Computer simulations can create an environment that is well suited for exploratory or discovery learning (Njoo & de Jong, 1993). According to Reimann (1994),

> Most exploratory learning environments and instructional simulations in particular are based on the principle of learning by induction: The student can generate for herself specific instances and is supposed to generalize over such observations or experiments. From this point of view, the pedagogical idea behind simulation environments is completely in line with the idea in concept acquisition and problem solving research, namely, that learning consists of discarding specific, and superficial information in favor of general, abstract information. (p. 1)

Some favorable assumptions concerning the use of simulations as an instructional tool that were derived from the literature (Dede, 1987; Lee, 1994; Smith, 1986; Smith & Ragan, 1993; Taylor & Walford, 1978) include:

- Simulations provide learners with the opportunity for problem solving and decision making, which deepens the understanding of these strategies or the domain-specific content.
- Simulation techniques are effective instructional tools for facilitating the achievement of cognitive (e.g., critical thinking skills) and affective outcomes.
- Simulations tend to increase student motivation due to heightened interest in the learning process.
- In simulations, learners are separated from "conventional wisdom", therefore, forcing learners to devise strategies, analyze results, and draw conclusions based on direct experience.

- Simulations remove student-teacher polarization. The teacher's role is that of interpreter or coach, not evaluator. The student's role become one of self-monitor and self-evaluator.
- Simulations have a dynamic framework—a larger number of time perspectives (e.g., past, present, future) are possible within a single simulation.
- Simulated environments increase role awareness.
- Simulations bridge the gap between schoolwork and "real world."

Some **advantages** simulations may have over other more traditional methods of instruction as identified by the literature (Dede, 1987; Lee, 1994; Taylor & Walford, 1978; Towne, 1995) are that they:

- Can provide learners with immediate and continuous reinforcement and practice.
- Can alter time and space for instructional value.
- Can provide task-focused and real-world experiences.
- Can be used to assess use of metacognitive skills.
- Can be easily related to learning theories.
- Are usable at any age, children to adults.
- Can present an interdisciplinary view and provide multiple representations.

Some **disadvantages** of simulations as outlined in the literature (Dede, 1987; Lee, 1994; Taylor & Walford, 1978) are that they:

- Can be time consuming and difficult and costly to create.

- May cause operational problems for teachers and learners who are unfamiliar with simulations (e.g., management techniques, logistics of classroom).
- May cause problems for low ability students in transferring learned skills to "real-life situations.
- Can require problem solving when students are unskilled in underlying concepts and principles leading to cognitive overload.

Simulated learning environments are considered to be effective in terms of providing computer-based instruction; however, the design features of this type of learning environment may not be conducive to all types of learners. Therefore, adaptive instruction, which varies the method of simulation-based instruction, learning sequence, or lesson content to meet the specific needs of learners in certain instructional situations, should be a major consideration.

Integrating technology into an educational setting can be very challenging. Consideration must be given to: (a) technology formats and capabilities, (b) instructional methods, (c) type and complexity of learning task, (d) cost of integration, (e) evaluation procedures, and (f) theoretical foundations. Land and Hannifin (1996) contend that one of the major challenges for instructional designers will be to take advantage of the instructional techniques, 'scaffolds,' to help bridge the gap between a learner's current skill level and a desired skill level" (Kao, Lehman, & Cennamo,

1996, p. 302). In order for scaffolding to be capabilities of emerging technologies, while generating new designs based on psychological and pedagogical research and theory.

Need for Instructional Support in Exploratory Learning Environments

Learning is influenced by learner, task, and environmental variables (Smith and Ragan, 1993). Learner variables refer to such factors as prior knowledge, information processing preferences, the use of learning strategies and self-regulation skills (e.g., motivation, allocation, attention, attribution, attitude). Task variables include factors such as, type of learning task (e.g., declarative, conceptual, principle, procedure, affective, psychomotor) and degree of difficulty (e.g., simple or complex). Environmental variables reference such factors as time, agency mission, facilities, social context, and educational philosophy.

The degree of instructional support needed should be based on characteristics of learners, task, and context. Learner variables appear to be the most critical (Smith et al., 1997). For example, novice learners often need instructional support when engaged in exploratory learning environments (Jih & Reeves, 1992; Jonassen, 1986; Wilson, 1996). Scaffolding "uses a variety of instructional techniques, 'scaffolds', to help bridge the gap between learner's current skill level and a desired skill level" (Kao, Lehman, & Cennamo, 1996, p. 302). In order for scaffolding to be successful, Greene and Land (2000) contend that it is important that the learner recognize the usefulness of the scaffold and that the scaffold be flexible enough to engage the learner at his/her current level of understanding. Scaffolding techniques, such as, conceptual models and orienting devices (e.g., attention getting devices, pre-questions, learning objectives/goals and advance organizers), provide learners with varying degrees of instructional support and guidance. These scaffolding techniques may provide a means for alleviating the problems of disorientation, cognitive overload, knowledge representation that can occur in computer-based instruction, especially interactive multimedia (Jih and Reeves, 1992; Kenny, 1993). Some research studies support the notion that "scaffolding can enhance comprehension, improve independent learning, and promote knowledge transfer" (Kao et al., 1996, p. 302). However, more empirical studies are needed to provide substantive supporting evidence.

Collins (1996), who strongly believed that scaffolding helps students accomplish difficult tasks and provide focus at critical times, did point out that scaffolding sometimes becomes a "crutch" to learners; therefore, "scaffolding should be faded as students become more expert" (p. 357). A major challenge for instructional designers is to learn how to make effective use of the various capabilities of exploratory learning environments to assist the learners while avoiding the inherent problems (Kenny, 1993).

Instructional design considerations for integrating scaffolding into a learning environment are just as important as any other instructional support tool. Determining task complexity, in addition to type and level of support, are basic considerations.

As a part of their study, Kao et al., (1996) developed a 3-D contingent scaffolding model that was designed to provide a systematic approach for linking the concept of scaffolding to the integrated media design features using both building and fading techniques. This model allowed the teacher/designer to adapt a level of support based on the learner's performance in a learning task using a series of steps and sub-tasks. They tested this model in their study to determine how effective it was at designing scaffolding instruction by integrating the model into a computer-based instruction program, "Hypothesis Testing—the Z test, to create a hypermedia-based learning environment.

Although not statistically significant, the findings did show evidence that the program did enhance retention and improve learning.

In recent years, the literature reflects a trend of investigating the effects of creating learning experiences of an exploratory or generative nature by using the Internet/World Wide Web (WWW). The WWW is changing the way we deliver instruction and introduce learners to real-life situations. Some educators view the "web" as a tool for engaging learners in a variety of "rich" and "authentic" learning experiences because of its access to a plethora of information sources.

Norton and Wiburg (1998) described an instructional design tool called "WebQuests," an inquiry-oriented activity developed by Bernie Dodge. The primary purpose of WebQuest is to facilitate knowledge acquisition and integration (short-term WebQuest) and to facilitate the extension and refinement of knowledge (long-term

Norton and Wiburg (1998) described an instructional design tool called "WebQuests," an inquiry-oriented activity developed by Bernie Dodge. The primary purpose of WebQuest is to facilitate knowledge acquisition and integration (short-term WebQuest) and to facilitate the extension and refinement of knowledge (long-term WebQuest) by having students interact with information on the Internet. A WebQuest designed for problem solving should contain the following elements:

1. An introduction that sets the stage and provides some background information;
2. A task that is doable and interesting;

3. A set of information resources relevant to solving the task;

4. A description of the process that learners should use to accomplish the tasks;

5. Some guidance on how to organize students' time and resources as well as information; and

6. A conclusion that brings closure to the quest, reminds learners what they have learned and accomplished, and perhaps encourages then to extend the experience. (Norton and Wiburg, 1998, p. 181)

WebQuest can be designed to include group activities, motivational elements, and interdisciplinary tasks. Also, WebQuest can engage learners in various thinking skills such as, classifying, constructing, comparing, inducing, deducing, abstracting, and analyzing.

Land and Greene (2000) conducted a qualitative study on project-based learning using the WWW. More specifically, they sought to investigate the learning process employed by learners to seek, locate, and integrate information resources when engaged in a project-based environment. The following research questions guided this study: (a) What general strategies do learners use to guide their information seeking?; (b) What are the roles of system, domain, and metacognitive knowledge in locating WWW resources?; and (c) To what extent do learners integrate WWW resources into a coherent paper?

An analysis of the data collected revealed the following findings: (a) Progressing from data-driven to goal-driven approaches was critical to developing coherent project ideas; (b) Consolidation of information resources with project methods and rationales was challenging for learners, often resulting in topic "drifts" or idea simplification; and (c) system, domain, and metacognitive knowledge appeared critical to achieving coherence in project development.

The following implication for instructional design were derived from their analysis of the findings:

1. There is an apparent need for external support mechanisms that help learners develop strategies for effective learning with project-based environments. (p. 61)
2. Teachers and designers should plan for varying levels of student knowledge in all three areas (system, domain, and metacognitive) rather than trust self-reports of their knowledge or presume that learning is occurring productively. (p. 62)
3. Incorporating methods to increase the monitoring of students during project development would allow instructors to engage in more dynamic assessment of individual learner needs that could lead to a more sensitive instructional support. (p. 62)
4. Reflection on past experiences function as a scaffold for organizing and integrating new project conceptions—engaging in metacognitive processing. (p. 64)
5. Providing "en route" or dynamic assessment and support for learner progress seems most critical. (p. 64)
6. Increased instructional or scaffolding should focus on helping learners reflect on and articulate their on-going understanding in a complex learning

environment. Such scaffolding may enable learners to achieve greater coherency and experience less frustration. (p. 64)

Some of these instructional design implications are congruent with Kao's et al., (1996) scaffolding design elements: (a) hierarchical component skills, (b) decreasing support levels, (c) repetitive authentic practice, and (d) on-going assessment. For example, Implications 2, 3 and 6 reflect the suggested design element of "on-going assessment—measuring learner's progress against the global picture of the task and make correction when needed, probably at the end of each component skill.

Land and Greene (2000) described two electronic software systems that provide opportunities for monitoring and evaluating the learning process. The first system, STAR.legacy, was developed by Schwartz, Lin, Brophy, and Bransford to encourage on-going reflection of the learning process by both teachers and students (cited in, Land & Greene, 2000). The second system involved the use of telecommunications software to scaffold authentic, project-based inquiry (Laffey, Musser, and Wedman, 1998, cited in Land & Greene, 2000). Whether these instructional design systems are a valid and reliable means for assessing a student's current mastery level and for providing a means to evaluate an instructional process is yet to be determined.

Implication 4 reflects the suggested design element of repetitive authentic practice—setting up a sequence of authentic practice involving the performance of the same skill, thereby leading to task mastery and transfer.

Another qualitative study, Greene and Land (2000), was conducted for the purpose of investigating the effectiveness of scaffolding in a resource-based learning environment involving the WWW. This study combined data from the four cases investigated in Land and Greene (2000) with data from four additional cases—18 undergraduate students. They sought to answer the following research questions: (a) How did learners use WWW resources to develop projects in a resource-based learning environment?; (b) How did procedural scaffolding influence project development in a resource-based learning environment?; (c) How did student-student interactions influence project development in a resource-based learning environment?; and (d) How did instructor-student interaction influence project development in a resource-based learning environment involving the WWW?

Three general themes were derived from their study:

1. **A critical need for resources to be accessible to learners**

   Learners used the procedural scaffold to help them make their ideas overt but were of limited usefulness in supporting evaluation of the reasons behind the idea. Learners seem to need help from the instructor in accessing underlying principles. There appeared to be a need for more overt scaffolds to help novice learners discover the utility. This theme seems to suggest a need for a system with multi-level support mechanisms that could adapt instructional support to meet the individual learner's needs, for example, Kao's et al., (1996) four-level scaffolding design model.

2. **The resilience of naïve conceptions**

   Students had difficulty recognizing limitations in their thinking about how to use and conceptualize the WWW as a tool for learning. Students were reluctant to let go of their naïve conceptions. This theme coincides with research results on the effects of preexisting beliefs and biased and confounded meanings (i.e., mental contamination) on student learning (Land & Hannifin, 1998) and seems to suggest a possible deficiency in the metacognitive skill of self-regulation.

3. **The need for dynamic, social scaffolding**

   Dialogues with peers and instructors seem to enhance more abstract thinking, reflecting, and reasoning about their projects. Instructor interaction was significant. This theme supports the assumption of "social scaffolding" (Greene & Land, 2000) and "shared meaning" (Land & Hannifin, 1998). Teacher-student interactions and student-student interaction are thought to be very beneficial in helping learners understand and conceptualize desired project goals. By integrating technology into educational learning environments, designers can facilitate teacher-student interactions and promote learning that is more student-centered and cooperative (Baron and Orwig, 1997).

Exploratory learning environments, although considered to be an effective tool for creating authentic experiences and providing adaptive instruction, still have problems and limitations that need to be addressed. One major concern discussed in the literature (Kao et al., 1996) is that scaffolding techniques should be "faded" as learners become more independent in their learning. If the "fading" process does not occur, this could negate the primary intent of scaffolding, which is to help learners become proficient enough to be independent learners. Another issue seems to be determining when support should be faded and how much support should be reduced at the time (Kao et al., 1996). To be able to make these decisions, the learner's current mastery level must be known. Again, there is an apparent need for systems that can monitor and assess learners' mastery levels.

Instructional designers and teachers must realize that technological support alone is not the answer to effective instruction and learning. Time and effort must be spent in designing and prescribing instruction based on sound theories and principles and empirically based research, both qualitative and quantitative. To date, qualitative studies in this area of research are few. Additional qualitative studies could focus on such things as: (a) learners' likes and dislikes concerning exploratory learning environments, (b) learners' interactions with the various types of interactive media, and (c) learning strategies used by learners engaged in problem-solving activities.

These design and implementation limitations present great challenges for instructional designers and teachers. One of the potential advantages of exploratory learning environments is that they can be designed to meet the individual needs of learners. When developing technology-based learning environments, such as open learning environments, instructional design principles and models (e.g., adaptive instructional models) should be used in the development and design of instruction. Both traditional (e.g., Gagné & Briggs, 1979) and more recent (e.g., Wilson, 1995) instructional design models support the concept that learners need instructional support, but at varying degrees. However, these models differ somewhat on how instructional support should be initiated. Gagné and Briggs's (1979) instructional events suggest a more rigid, supplantive approach (externally generated strategies), in contrast to Wilson's (1995) "situated" ID model which suggested a more situation-adaptive, generative approach, supporting the use of learner generated strategies. This approach involves adapting instruction according to the restraints of a given situation using criteria such as learner characteristics, learning task, and learning environment. According to Wilson (1995), adaptation and conceptual model provision are necessary ingredients in designing "situated" instruction, for example, helping learners relate abstractions to concrete realities.

Adaptive Instructional Models

A central research paradigm in instructional technology practiced since the advent of computers in education is to provide empirical substantiation of guidelines and theoretical models for adapting instruction to individual learner differences, including prior knowledge, aptitude, cognitive style, etc. Adaptive instruction prescribes the methods for changing the form of instruction to accommodate needs and desires of individuals and is based on the assumption that individuals differ in terms of their performance when given a single instructional treatment (Jonassen & Grabowski, 1993). Adaptive instructional models are designed to accommodate individual differences in learners' abilities and styles by adapting the method and sequence of instruction to eliminate the effects of those differences (Jonassen, 1986).

Adaptive instruction models can also adapt to contextual and learning tasks differences. Several recent studies that have investigated this particular area of research are: Darwazeh (1994), Njoo and de Jong (1993), Smith (1992), and Smith, Ragan, McKay, and Rezabek (1997). From these studies, implications for adaptive instruction have been generated. However, what is lacking with many of these adaptive models is validation by means of empirical research.

Darwazeh (1994) conducted a meta-analysis of literature related to cognitive strategies, using experimental studies, for the purpose of investigating the effects of embedded and generative cognitive strategy systems on difference instructional variables (i.e., learner characteristics, content characteristics, learning level) resulting in two prescriptive models for designing instruction. An embedded cognitive strategy system is an instructional system "in which learners are forced to use a given cognitive strategy activator that was prepared by the teacher/designer/researcher," where as, a generative cognitive strategy systems is one "in which learners are directed to generate a certain cognitive strategy activator themselves" (Darwazeh, 1994, p. 3). The learner characteristics addressed in this study were (a) high vs medium vs low ability students, (b) *field dependent vs independent learners,* and (c) trained (i.e., teacher provided strategy) vs untrained (i.e., learner-generated strategy). In the area of content characteristics, the categories included: (a) organized vs random, (b) familiar vs unfamiliar, and (c) specific to general sequencing vs general to specific sequencing. With respect to levels of learning, the categories were: (a) high (i.e., application analysis, synthesis, problem solving, evaluation), (b) medium (i.e., comprehension), and (c) low (i.e., retention/recall).

Darwazeh's meta-analysis of embedded cognitive strategy systems and generative cognitive strategy systems compared and contrasted the literature based on three major categories: (a) the overall systems of embedded and generative learning, (b) the position of the cognitive strategy activator (i.e., pre- or post-position), and (c) the mode of the cognitive strategy activator (i.e., concrete (visual) or abstract (written)).

After reviewing the literature comparing the two systems, Darwazeh (1994) concluded that the generative system appears to be more effective in increasing students' learning than the embedded system. However, each system has advantages over the other based on the interaction of various instructional variables such as learner characteristics, content characteristics, and levels of learning. For example, the embedded cognitive strategy activators were more effective under these conditions: (a) low and medium ability students, (b) *field-dependent learners*, (c) untrained students, (d) organized learning content, (e) familiar learning content, and (f) low and medium levels of learning. On the other hand, generative cognitive strategy activators were more effective under these conditions: (a) high ability students, (b) *field-independent learners*, (c) trained students, (d) random learning content, (e) unfamiliar learning content, and (f) low, medium and high levels of learning.

Darwazeh's analysis of the literature comparing the position of cognitive strategy activators (pre- or post-position) in instruction, led to the conclusion that the post-cognitive activators (i.e., instructional support material administered after instruction/treatment) are more effective than the pre-cognitive activators (i.e., instructional support material administered before instruction/treatment) in increasing learning. There are, however, advantages and disadvantages based on different instructional variables. For example, the pre-cognitive strategy activators appear to be more effective under these conditions: (a) low ability students, (b) learning content sequenced from specific to general, and (c) low levels of learning. On the other hand, post-cognitive strategy activators appeared to be more effective under these conditions: (a) medium and high ability students, (b) learning content sequenced from general to specific, and (c) low, medium, and high levels of learning.

In terms of the mode of cognitive strategy activators, Darwazeh (1994) found that visualized cognitive strategy activators appear to be more effective than oral or written cognitive strategy activators. Effective use of the various modes depends highly on the different instructional variables that interact with the mode. She suggested that visual cognitive strategy activators were more effective under these conditions: (a) low ability students, (b) unfamiliar learning content, and (c) low and medium levels of learning. On the other hand, written cognitive strategy activators were more effective under the following conditions: (a) high ability students, (b) familiar learning content, and (c) high levels of learning.

Darwazeh's (1994) overall conclusion to this study is that the generative system is generally more effective in increasing student learning than the embedded system; however, each system has advantages over the other under certain conditions. Therefore, the effectiveness of the two systems of instruction appear to be related to their interaction with various instructional variables such as, learner characteristics, content characteristics, and levels of learning. The belief that neither approach to instruction is necessarily better than the other, but successful learning in one approach or the other may be attributed to other factors that may influence the effectiveness of the instructional approach was shared by others as well (Jonassen, 1994; Smith, 1992; Smith & Ragan, 1993).

Another prescriptive model for designing adaptive instruction is Smith's (1992) COGSS (Choice of Generative /Supplantive Strategies) model. Smith (1992) proposed the use of this model as a guide for making decisions about the level of instructional support for a domain-specific problem-solving lesson. The COGSS model was designed to help instructional designers/teachers select instructional strategies most appropriate for a particular instructional situation. The model prescribes whether the degree of "cognitive processing support" should be more supplantive or more generative based on three different categories of variables: learner characteristics, learning task characteristics, and contextual (i.e., setting) characteristics. For example, if the learning task has been classified as complex, the model prescribes the use of more generative instructional strategies. On the other hand, if the task has been classified as simple, the use of more supplantive instructional strategies is prescribed.

Smith, Ragan, McKay, and Rezabek (1997) used this model as a theoretical framework for their study that sought to investigate the effectiveness of orienting devices on problem solving using a highly exploratory, computer-based simulation. Instructional treatment involved three different levels of orienting techniques (single complex problem, three simple problems plus complex problem, and no orienting device). Learner characteristics measured in the study were attribution of learning success/failure, specific prior knowledge, interest in the topic, prior experience with topic, effort, and computer playfulness.

The instruments used to measure learning performance were: (a) a 15-item multiple-choice test designed to measure learners' abilities to apply photography principles and (b) a four-item constructed response test, which required learners to solve a simple contextually-based problem and complex, contextually-based problems. The learning environment was a computer-based "stripped down," "unwrapped" simulation. The subject-matter content was photography, and the simulator was divided into three sections: shutter speed, aperture, multiple input (i.e., shutter speed and aperture). The only instruction given to the subjects was the suggestion of three different learning goals, depending upon assigned instructional treatment, presented on three separate sheets which were stated as follows: (a) "explore until you feel you could solve a problem like this one (conditions regarding subject, lighting, object movement, and desired result are presented with solution requiring determination of correct combination of shutter speed and aperture); (b) explore until you feel you could solve problems like these (four problems presented, three single principle application, one problem solving (multiple principles selected and applied); and (c) explore until you feel you understand the topics presented" (p. 5).

Prior to instructional treatment, the subjects, 104 undergraduate students, were asked to respond to several survey instruments: Classroom Learning Attribution Scale, Computer Playfulness Scale, Prior Knowledge Survey, and Interest in Photography Scale. Data from the study were analyzed using a variety of techniques. A 1 x 3 ANOVA was conducted to compare achievement scores of the three treatment groups, and multiple regression analyses were used to examine the interaction effects of the three different orienting techniques and learner characteristics.

Results from the data analyzed showed wide variations in performance; however, these variations could not statistically be linked to variations in orienting techniques on learner characteristics. On Test 1, the type of orientation revealed no statistical significance in groups; and after prior knowledge was partialed out, there was no statistical difference among the groups. Also, the analysis of data did not indicate any significant interaction between orienting instruction and learner variable on learning performance. However, interest and effort were moderately and significantly correlated with Test 2 scores. A hierarchical regression analysis was conducted which investigated the effects of treatment group and learner characteristics on Test 1 and Test 2 performance. The proportion of variance of scores accounted for by the various models ranged from 2 percent to 20 percent. The vast majority of the variance in both tests was unaccounted for by either group membership or by learner characteristics.

Smith et al. (1997) drew the following conclusions from this study:

- The difficulty of learning complex material in a purely exploratory learning environment is often underrated. Even for learner who may possess ideal characteristics for learning under such condition, it is all too easy to create environments at the far generative end of the continuum in which insufficient learning guidance is provided.
- Moderate supplantation in the form of prompting might significantly affect the quality of instruction.

These authors proposed some additional learner variables that might be considered for future research are: persistence, interpretation of personal relevance, and abilities and willingness to note and interpret feedback, ability to select manipulations that would highlight underlying principles, ability to formulate principles that account for their observations, ability to make predictions based on nascent principles and ability to develop a strategy for testing out these predictions. According to Smith et al. (1997), these variables may have had an impact on performance in their study.

Njoo and De Jong (1993) conducted two earlier studies similar to Smith et al. (1997). The purpose of these two studies was to gain more knowledge about exploratory learning in general and to assess the effects several instructional support measures on exploratory learning. The subject-matter domain for their study was "control theory," which is a subdomain of mechanical engineering.

The primary purposes of the first study (*Study 1*) were to: (a) identify exploratory learning processes—specific mental actions of learners and (b) assess the effects of providing instructional support to learners in the form of hints on the use of specific learning processes (i.e., hypotheses generation and testing). In a previous study (Njoo & de Jong, 1991) conducted by these authors, they found that many learners did not act as explorers and are reluctant to use specific exploratory learning processes.

Study 1 involved 17 university students who were randomly assigned to eight different groups. The subjects worked in pairs with one group consisting of three subjects. The subjects were assigned to one of two experimental conditions based on their average score on three prior, introductory courses. Those subjects having an average score of 70 percent or higher were classified as "good" and the subjects having an average score of less than 70 percent was classified as "poor." Half of the groups (unguided) received no guidance, and the other half (guided) were given hints for hypotheses generation and testing. For example,

> **unguided group:** What is the reaction of the system on a step in u(t)?
>
> **guided group:** What is the relation between the step response and the location of the poles? Make a prediction of the reaction of the system to a step in u(t); verify your prediction. Justify your answer (Njoo & de Jong, 1993, p. 824).

The researchers hypothesized that the "guided" group would be more likely to use hypotheses generation and testing.

To identify the specific learning processes of the subjects, think aloud protocols were used, as well as log files (on-line registration of subjects' input and output), notes made by subjects, and notes made by a tutor. An analysis of these data and a review of related literature resulted in the identification of four exploratory learning processes: (a) *transformative processes* which referred to the scientific inquiry process (i.e., analysis, hypotheses generation, testing, evaluation), (b) *regulative processes* which referred to the executive control processes (e.g., planning, monitoring), (c) *operating the simulation* which referred to the users interface with the simulation program, and (d) *general nature* which referred to basic skills such as, calculating and interpreting.

An analysis (using *t*-tests) of the data collected on the exploratory behaviors of the "guided" and "unguided" groups indicated no significant differences between the two groups, $p < .05$. It appears that the provision of hints did not facilitate exploratory behaviors. These results were consistent with the researchers' previous study (Njoo & de Jong, 1991).

Another important finding was that the learning processes most essential to exploratory learning, such as hypotheses generation, designing an experiment, and manipulating variables were almost nonexistent. Also it seemed apparent that subjects could have possibly benefited from additional domain-specific knowledge.

Study 2 also had a two-fold purpose: (a) assess the influence of instructional support (i.e., fill-in forms and information sheets) on specific exploratory learning processes and (b) assess the effects of providing hypotheses on exploratory learning behaviors. Ninety-one mechanical engineering students were divided into 44 pairs (some pairs consisting of three students). Ten pairs of subjects were placed in the control group, which received no additional support; the remaining pairs of subjects were randomly assigned into four different experimental groups. Subjects in the experimental groups received: (a) specification of a modeled system (i.e., a ship that had to be kept on course), (b) an open-ended assignment to explore the model system with the aim of constructing the optimal regulation for the system, and (c) additional support in the form of an information sheet and fill-in forms. Two variations of the information sheet (general or domain-specific) and two variations of the fill-in forms (free or hypotheses) were used in the study.

The information sheets, which were given out at the beginning of the lab session, contained information on a number of exploratory learning processes (i.e., global activity, learning process validity, domain correctness, consistency, overall strategy). After reading the information sheets, the subjects were instructed to work with the simulation using the fill-in forms. These fill-in forms offered the subjects the opportunity to write down their thoughts, actions, or results of the simulation for each of the exploratory learning processes. The information sheets and fill-in forms were divided into six cells labeled VARIABLES and PARAMETERS, HYPOTHESES, EXPERIMENT, PREDICTION, DATA INTERPRETATION, AND CONCLUSION. Subjects were asked to read the information sheet carefully and work though the assignment by completing the fill-in forms in no specific order. Subjects' statements from the fill-in forms were assessed based on the following five levels of analysis:

global activity—defined by the number of forms used and the total number of cells completed.

learning process validity—an assessment of aspects of the cell statements given by the subjects.

domain correctness—an assessment of the domain-specific aspects of cell statements that had proven to be learning process valid at the previous level.

consistency—an assessment of the relations between contents of different cells on one fill-in form.

overall strategy—an assessment of the development of the statement in the same cell through different forms.

The results from the analysis of data indicated a strong main effect of the type of fill-in form on the total number of forms used. An average of 5.5 forms were used by subjects given the hypotheses fill-in forms compared to 3.7 forms used by subjects given the free fill-in forms. There appeared to be a higher activity level (i.e., longer time engaged with instructional materials) for the groups receiving the hypotheses fill-in forms. The type of information sheet (i.e., general or domain-specific) apparently had no effect on the number of forms used. Subjects given the hypotheses fill-in forms used on an average of 89.5 percent of the cells provided compared to the subjects given the free fill-in forms who used 78.7 percent of the cells. Although the groups receiving the hypotheses forms showed a higher level of *global activity*, there was very little engagement in "free" activity—self-generated exploration.

When the data was analyzed for *learning process validity*, there was a significant effect found only for the cell CONCLUSION. Both the information sheet and fill-in forms showed significant effects for this cell, ($p < .01$). The hypotheses groups performed better (30.5%) in the CONCLUSION cell than the free form groups (18.8%). The researchers believed that the provision of valid hypotheses accounted for the difference in scores. Groups given the domain-specific sheets scored higher (29.3%) than the groups given the general information sheets (21.4%). The domain-specific sheets appeared to be more helpful for the exploratory learning processes.

Analyzing the data for *domain correctness* showed a significant effect from the experimental condition fill-in forms on the scores in the cell CONCLUSION indicating that the subjects who had received hypotheses scored higher. Also contrary to researcher's expectations, provision of domain-specific information sheets had no apparent effect on learner performance.

In the assessment for *consistency*, the data showed that 90.1 percent of the relations given by all the subjects together were correct, leading the researchers to conclude that learning process validity and domain-specific statements resulted very often in correct relations. Results from the analysis of *overall strategy* (i.e., the development of successive hypotheses and the relationship between a hypothesis and the conclusion of the previous fill-in form) were not conclusive due to insufficient data. The participants generated only a few hypotheses; and the hypotheses that were generated usually were not successive.

At the end of the lab session, a seven-item multiple choice posttest was given. The questions were designed to test "qualitative insight" in the domain. The mean score of the posttest was 4.8. Three of the four experimental groups scored 4.7 or 4.8, the *domain specific—hypotheses* group scored 4.3, and the *control* group scored 5.2. The only significant difference found was between the *domain specific-hypotheses* group and the *control* group, ($t = 2.33, p < .05$).

Njoo and de Jong's (1993) overall opinion was that providing learners with instructional support measures that specifically train learners to use exploratory skills could possibly improve exploratory learning. The authors believed that the lack of supporting evidence could be attributed to the participant's unfamiliarity with the type of learning processes they were required to use (e.g., hypothesis generation and prediction making). The participants appeared to have some difficulty distinguishing between a hypothesis and a prediction. Njoo and de Jong (1993) thought that more significant results could have been found if the participants had more experience with the learning processes used in this study. They also emphasized the need for additional studies that relate learner attributes to instructional support and domain characteristics.

A basic question that has been debated in the literature is what kind of or level of instruction support or guidance is needed for learners engaged in exploratory learning environments. Several scholars (Darwazeh, 1994; Jonassen & Grabowski, 1993; Smith, 1992; Smith et al., 1997) proposed the use of adaptive instruction models for designing instruction to accommodate certain learner characteristics, learning tasks, and learning context. Smith (1992) and Darwazeh (1993) presented adaptive instruction models they thought could be used as guides for making decisions about the degree of instructional support needed (i.e., generative or supplantive) given certain learning situations. A similar overall conclusion drawn from both studies was that neither approach to instruction is necessarily better than the other, but successful learning in one approach or the other may be attributed to other factors that may influence the effectiveness of the instructional approach.

Njoo & de Jong (1993) and Smith et al. (1997) both investigated the effects of instructional support measures on exploratory learning. Statistically significant results were not found for the different treatments in either study. However, both studies seemed to agree that exploratory learning can possibly be enhanced by instructional support measures, if other learner variables and domain characteristics are considered.

The research design of this study was adapted from Smith et al. (1997). The purpose of this study was to provide empirical evidence to support the notion of using a conceptual model to facilitate mental model development and the learning of certain instructional tasks by particular types of learners who have been identified as having different cognitive styles.

Overview of Schema Theory and Mental Model Theory

Not having developed an appropriate mental model of the target system could possibly affect the problem solving ability of novice learners. As mentioned in the previous section, novice learners often need instructional support when engaged in exploratory learning environments to help them build the appropriate mental model of the phenomena being studied. Therefore, this section will attempt to provide a theoretical basis that supports the notion that learners perform better at problem-solving when they can represent knowledge appropriately.

According to Driscoll (1994), "developments in schema theory and mental model theory came on the heels of cognitive information processing theory, perhaps to better account for procedural behavior" (p. 141). Both of these theories provide implications for instructional design considerations in terms of knowledge representation, storage, and retrieval of information in the memory. All of these processes are important elements in designing instruction to meet particular needs of various types of learners and identifying ways to provide instructional support to learners engaged in various types of learning activities.

Schema Theory

Schema theory is based on the assumption that knowledge is organized into data structures that contain "slots"—also referred to as "units," "packets," "place holders," or "attributes"—in the memory (Anderson, 1990; Driscoll, 1994; Kardash, Royer, &

Greene, 1988; Rumelhart, 1980; Schunk, 1991). These data structures, including slots, are referred to as schemata. Each slot is associated with a certain aspect that can vary according to context (e.g., person, object, event, idea, situation). Schemata are types of knowledge representations that are learned and used during interaction with the environment (Anderson 1990; Schunk, 1991).

According to some theorists, schemata are the foundation upon which the theory of information processing is based (Rumelhart, 1980). They are active and can adapt and change during learning and mental development by the integration of new information and experiences into existing schema (i.e., assimilation) and by the modification of existing schemata or creation of new schemata (i.e., accommodation) (Driscoll, 1994; Rumelhart, 1980; Schunk, 1991). According to Rumelhart (1980), schemata facilitate five basic cognitive functions: (a) perception, (b) understanding of discourse, (c) remembering, (d) learning, and (e) solving problems. Other beliefs about schemata are that they:

- facilitate encoding because they elaborate new material into meaningful structures (Schunk, 1991),
- facilitate recall independently of their encoding effects (Kardash, Royer, & Greene, 1988; Schunk, 1991),
- facilitate inferencing about concepts (Anderson, 1990; Driscoll, 1994),
- allow learners to make predictions about unobserved events or situation (Anderson, 1990; Driscoll, 1994),
- serve as a basis for predicting missing information and correcting errors (Anderson, 1990),

- facilitate transfer of knowledge to other subject matter domains (Schunk, 1991).

As learners attempt to integrate new material into existing schemata, less important or optional schemata may or may not be learned; therefore, teachers should consider facilitating students development of schemata by means of providing it as instructional support (Schunk, 1991). Schunk argued that helping learners develop the correct schemata and make the appropriate links to existing schema can facilitate learning. Using a conceptual model to help learners represent knowledge and build appropriate schemata would be an example of what Schunk (1991) proposed.

Mental Model Theory

Mental model theory attempts to explain how large amounts of knowledge is acquired and conceptualized by the learner (Driscoll, 1994). Mental model theory explains the higher cognitive processes of comprehension and inference and suggests that the mind consists of recursive procedures, propositional representations and models (Johnson-Laird, 1983). Individuals develop mental models as a result of their interaction with the various kinds of stimuli in the environment (Johnson-Laird, 1983; Norman, 1983). Mental models are mental representations (i.e., knowledge representations) resulting from interaction with the environment that drive an individual's performance (Driscoll, 1994; Gagné & Glaser, 1987). Mental models are schema-based and perception-based; they help the learner perceive task demands, predict task performance, and make inferences (Driscoll, 1994; Gagné & Glaser, 1987; Gott, Lajoie, & Lesgold, 1991). Mental models can be verbal or visual, concrete or abstract.

A Comparison of Mental Models and Schemata

Mental models and schemata are similar in that they both share some common characteristics:

- active and change as new information is learned
- contain declarative and procedural knowledge
- facilitate various types of learning—recall, retention, prediction, transfer, and problem solving
- are forms of knowledge representation

Mental models and schemata differ in structure and content (Johnson-Laird, 1983), for example:

- Mental models are highly specific; schemata are more of a general class of entities.
- Schemata tend to handle both determinate and interdeterminate spatial relations on an equal basis, where as, mental models tend to handle determinate spatial relations more readily than interdeterminate ones.
- Schemata are strings of symbols that correspond to natural language; mental models are structural analogues of the world.
- Schemata appear to be special cases of procedures for constructing mental models and are interpreted with respect to mental models.

It is apparent that mental models and schemata are interrelated and both impact how knowledge is represented in the mind.

As individuals continue to interact with the environment, particularly when learning a target system, their mental models become more efficient and flexible (Gagné & Glaser, 1987; Norman, 1983). Mental model development is believed to be affected by the individual's prior knowledge, including prior experience with the target system (such as and 35mm reflex camera), and information processing abilities (Norman, 1983). Experts seem to structure knowledge within a mental model around principles and abstractions (i.e., top-down processing), where as novices seem to structure knowledge around the surface features of what was actually presented to them in the problem statement (i.e., bottom-up processing) (Glaser, 1984 cited in Driscoll, 1994). Also, experts are generally guided by more than one mental model, for example, a problem space model that provides a broad representation of spatial position, a critical reference domain model that provides more depth to the problem, and critical device and component models that guide understanding and performance (Gagné & Glaser, 1987; Gott, Lajoie, & Lesgold, 1991).

When engaged in problem-solving activities, individuals tend to differ in how they build their mental models (Driscoll, 1994). Being able to solve problems effectively depends on the accurate construction of a mental model of a specific domain (Gagné & Glaser, 1987). It is plausible that experts and novices apparently do differ in terms of their mental model representations and usage, especially in the area of domain-specific content. These differences in mental model construction can influence learning performance. Gagné and Glaser (1987) argued that " children, or adults who presumably lack proficiency in abstract reasoning abilities, can be made to exhibit more proficient performance by fostering the use of mental models" (p. 72). Therefore, one type of instructional support may be to aid learners in knowledge acquisition so that the appropriate mental models can be created, thus facilitating performance. This new learning can include domain-specific knowledge and acquisition of self-regulatory skills. A method for facilitating mental model formation will be discussed in the section on the impact of conceptual models learning.

Measuring Mental Model Development

One of the challenges of mental model research is determining a valid and reliable method for measuring a dynamic and internal knowledge representation system. Gagné and Glaser (1987) suggested that such assessment will provide information needed to make decisions concerning the degree of instructional support a particular learner might need in order to perform specific types of tasks effectively. Assessment should be made of both the user's mental model of the subject-matter content (e.g., the relationship of aperture to depth-of-field) , as well as the user's mental model of the target system (e.g., the operation of a 35mm reflex camera) (Jih & Reeves, 1992).

How can users' mental models be measured/assessed? Some of the most common methods of mental model assessment include: (a) teach-back approach, (b) observation, (c) think alouds (verbal protocols), and (d) on-line protocols. Sasse (1991) conducted five different experiments, which tested various methods of measuring mental model development; those methods were:

1. Observe system users while they are operating the system.
2. Ask users to describe the program to a novice learner.

3. Ask users to predict behaviors of the program.

4. Ask users to describe using the target system.

5. Observe users learning the target system with a co-learner.

Based on the results of five empirical studies (Sasse, 1991) observing users' interaction with a computer system, teach-back approaches (e.g., #2 & #4) appeared to be more effective at measuring mental model development than the other methods. However, asking the user to predict the behavior of the target system given certain changes "is a good way of checking whether the user holds a representation which could be described as a surrogate model of the system" (Sasse, 1991, p. 74).

Norman (1983) sought to assess the mental models of subjects using a calculator through observation and "think alouds." He argued that psychological experimentations and observations that consider both representational and functional issues must be conducted if one desires to measure individuals' mental models. He also emphasized caution concerning the assessment of mental models:

> Let me warn the nonpsychologists that discovering what a person's mental model is like is not easily accomplished. For example, you cannot simply go up to the person and ask. Verbal protocols taken while the person does a task will be informative, but incomplete. Moreover, they may yield erroneous information, for people may state (and actually believe) that they believe one thing, but act in quite a different manner. All of a person's belief structures are not available to inspection, especially when some of those beliefs may be of a procedural nature. And finally, there are problems with what is called the "demand structure" of the situation. If you ask people why or how they have done something, they are apt to feel compelled to give a reason, even if they did not have one prior to your question. They are apt to tell you what they believe you want to hear (using their mental models of your expectations). Having then generated a reason for you,

> they may then believe it themselves, even though it was generated on the spot to answer your question. On-line protocols generated while in the act of problem solving and that give descriptions of activities rather than explanations are more reliable (p. 11).

To determine what effect, if any, the provision of a conceptual model will have on the development an individual's mental model, an assessment of his or her mental model prior to and after treatment will be necessary. No single method of assessing mental models can be said to provide a complete description of the user's model; therefore, it is believed that the use of several methods of assessment may provide a more accurate picture of the user's mental model.

<u>Impact of Conceptual Models on Learning</u>

Conceptual models, sometimes referred to as "pedagogical theories/models," "mechanical models," and concrete models, are "appropriate" representations of the target system; they are created by teachers, instructional designers, scientists, and engineers (Gagné & Glaser, 1987; Norman, 1983). Conceptual models are instructional support devices developed to help learners who have difficulty building new or modifying existing mental model representations. Knowing a learner's current state of knowledge, allows for the specification of what can be called "pedagogical theories" (Glaser, 1984). These "pedagogical theories" (i.e., conceptual models) are used to interrogate, facilitate representations, and correct the learner's model, thus helping the learner to organize new information into more accurate mental models (Gagné & Glaser, 1987). Young (1983) called the mental models that learners have that explain the operations of a system/device "users' conceptual models" and classified them into eight different categories: (a) strong analogy, (b) surrogate, (c) mapping, (d) coherence, (e) vocabulary, (f) problem space, (g) psychological grammar, and (h) commonality (i.e., a common data structure constructed by the observer that described the user's actions/behaviors with the target system). In order for conceptual models to be effective, they must meet three basic criteria: learnability, functionality, and usability (Norman, 1983). More specifically, Norman (1983) argued that conceptual models: (a) should not be too difficult for the user to understand, (b) should closely match the system image and facilitate user predictions and explanations of the target systems, and (c) should be easy to use and accommodate the human information processing structure. Conceptual models can be given prior to, during, or at the end of instruction.

When learners lack relevant prior knowledge, they usually rely on the use of general problem-solving strategies rather than specific domain (i.e., schema-based) strategies and thus lead to unsuccessful solutions of problems (Driscoll, 1994; Jonassen, 1997). Jonassen (1997) argued that the effective use of problem-solving strategies can also be affected by certain domain characteristics (e.g., well-structured vs ill-structured). Well-structured domains have well-defined parameters, for example, few solutions and solution paths, rules and principles. On the other hand, ill-structured domains have multiple solutions and solutions paths and many times do not clearly indicate which rules, principles, and concepts facilitate problem solving. Therefore, these domain differences should be taken into account when making decisions concerning the appropriate degree of problem-solving support. One possible way to compensate for learners' deficiencies and domain characteristics would be to provide some type of instructional support to learners, for example a conceptual model in the form of a graphic organizer or a concept map. Jih and Reeves (1992) argued that it is easier for novice learners to assimilate a conceptual model than to generate one.

Graphic Organizers and Their Use as Conceptual Models

The trends in conceptual model research seem to focus not so much on whether conceptual model provision is an appropriate tool for providing instructional support, but recent research questions seem to be geared toward determining: (a) what kind of conceptual models (e.g., graphic organizers, concept maps, causal maps, semantic maps) might facilitate learning in relation to other factors such as, cognitive style, learning tasks, and learning environments and (b) how supportive are these conceptual models in helping learners develop appropriate mental models, which can impact such learning tasks such as, recall, retention, prediction, transfer, and problem solving.

Graphic organizers can help students organize material and experience meaningful learning (Brookbank, Grover, Kullberg, and Strawser, 1999). According to Pruisner (1995), graphics can represent top-down and bottom-up thinking. Top-down graphics include chains, planning and flow charts, scales for weighing arguments, and concept maps that help in anchoring concepts and solving problems. Bottom-up graphics include pie charts, grids, and graphs that help with scanning, sorting and organizing information. Integrating the appropriate graphic organizer in instruction can facilitate understanding of relationships and the recognizing of critical details. Consideration should be given to using instructional support tools, such as graphic organizer, to help learners during the thinking process identify and link related concepts.

Graphic organizers, used in some instances as conceptual models, are visual representations (pictures or diagrams) that indicate relationships among concepts. They can convey vertical, horizontal, and spatial concepts (Jonassen, Beissner, & Yacci, 1993; Robinson & Katayama, 1998). Also, they can be used to activate relevant schema and to correct the activated schema so that new material may be assimilated (Jonassen, et al., 1993). "Graphic organizers provide a beneficial means by which students can organize material and experience meaningful learning" (Brookbank, Grover, Kullberg, and Strawser, 1999, p. 45). According to Pruisner (1995), graphics can represent top-down and bottom-up thinking. Top-down graphics include chains, planning and flow charts, scales for weighing arguments, and concept maps that help in anchoring concepts and solving problems. Bottom-up graphics include pie charts, grids, and graphs that help with scanning, sorting and organizing information. Integrating the appropriate graphic organizer in instruction can facilitate understanding of relationships and the recognizing of critical details. Consideration should be given to using instructional support tools, such as graphic organizer, to help learners during the thinking process identify and link related concepts.

Graphic organizers are thought by some researchers (Ausubel, 1960; Grabowski 1996; Jonassen 1993,1997; Mayer, 1979) to be effective in providing instructional support to learners; however, it appears that they do not affect all learners in the same way. Some learners tend to benefit from graphic organizers that promote generative learning, and others tend to benefit from graphic organizers that promote supplantive learning. According to Smith and Ragan (1993), graphic organizers can be used to facilitate schema building and can be of a supplantive nature (provided by the instructor) or of a generative nature (generated by the learner). These attributes make graphic organizers a very dynamic instructional tool that can be used to facilitate learning in a number of different ways.

Hawk, Mc Leod, and Jonassen (1985) describe two basic types of graphic organizers—participatory (partially completed) and final form (completed). With the participatory graphic organizer, learners are asked to fill in various blanks on the organizer as they interact with the target system or instructional text. Participatory graphic organizers (PGO) involve learners in a more generative learning activity. On the other hand, with the final form graphic organizer (FGO), learners are only asked to read and remember the information presented by the organizer, a more supplantive learning activity. Participatory graphic organizers seem to be more effective at facilitating student learning than final form graphic organizers because they require learners to engage in moderate generative learning, which seems to enhance immediate recall, retention, and transfer (Hawk, Mc Leod, & Jonassen, 1985; Kenny, Grabowski, Middlemiss, & Van Neste-Kenny,1991; Smith and Ragan, 1993; Spiegel, C. F., Jr. and Barufaldi, J. P., 1994).

Jonassen et al., (1993) identified several learner interactions associated with the use of graphic organizers as instructional support tools:

- Some learners may see the pictorial representations as irrelevant to learning goals.
- Some learners may not have the necessary metacognitive skills that can enable them to profit from graphic organizers.

- Mature readers tend to benefit more from graphic organizers than poor readers. Graphic organizers may actually confuse poor readers.
- Providing processing instructions that give detailed instructions to learners on how to use the graphic organizer may help learners who are not familiar with using graphic organizers.

Kenny, Grabowski, Middlemiss, and Van Neste-Kenny (1991) conducted a study to compare the effects of two different graphic organizers (i.e., participatory form and final form) on immediate recall and retention in a hypermedia environment—computer-based interactive video (CBIV). Expected results were that the participatory graphic organizer (PGO) would have a greater effect on immediate recall and retention than the final form graphic organizer (FGO) and that both the PGO and the FGO would have greater effect on immediate recall than on retention. Both the PGO and the FGO contained imagery (a diagram and pictorial elements) and instructions to the learner to analyze and categorize information from the material-to-be-learned.

As an extension to their study, Kenny et al., (1991) sought to determine if learners' analytic reasoning and holistic processing affected posttest score for both treatments. Expected results were that posttest scores for both treatments would indicate a positive correlation with analytic reasoning and holistic processing.

This study included 32 undergraduate nursing students of which 29 subjects completed all parts of the study. Subjects were randomly assigned to two treatment groups—PGO and FGO. The CBIV program presented a case study on "The Nursing Care of the Elderly Patient with Chronic Obstructive Pulmonary Disease." The CBIV program was divided into four modules; only three of the four modules were used in this study. Two versions consisting of eighteen multiple choice items were used as posttests. Five questions required direct recall and 13 were near transfer items. Internal consistency reliability (Kuder-Richardon Formula 21) was .63 for Form A and .60 for Form B. Subjects were asked to read a section of the graphic organizer immediately prior to completing each module. The PGO treatment group was asked to fill in the blanks in the organizer while doing the CBIV program or immediately after. Subjects were asked to complete the first posttest (immediate recall) after completing the final module and the second posttest (retention) one week later.

The Sheet Test (measurement for spatial holistic ability) was administered one week prior to treatment, and the Wechsler Adult Intelligence Scale Revised (measurement for analytical reasoning) was administered individually immediately before treatments began.

To test the first hypothesis that the PGO group would perform better than the FGO group on immediate recall and retention, planned contrasts were calculated using one-tailed t-tests. The results indicated no significant difference in mean scores on Posttest 1, PGO (M=13.5) and FGO (M=11.846); $t(50) = 1.097$, $p > .075$. Subjects in the FGO group did score higher (M=13.615) on Posttest 2 than did those in the PGO group (M=13.438). However, the difference was not significant, $t(50) = 0.572$, $p > .075$.

In testing the second hypothesis, which predicted that both treatment groups would have a greater effect on immediate recall than on retention, the results showed that subjects in the PGO group obtained a slightly higher mean score on Posttest 1 than on

Posttest 2; however, the difference was not statistically significant, $t(25) = 0.066$, $p > .075$. Contrary to the hypothesis, subjects in the FGO group scored higher on Posttest 2 than on Posttest 1. The difference was statistically significant, $t = 1.688$, $p < .075$.

In regard to the third hypothesis that predicted the mean posttest scores would correlate positively with the mean scores on the WAIS similarities subscale and on the Street Test, correlation coefficients on Posttest 1 for both factors were positive, WAIS (0.066) and Street Test (0.133), neither were statistically significant. Correlation coefficients on Posttest 2 indicated a negative correlation with WAIS (-0.298) and a positive correlation with the Street Test, but neither were statistically significant. Therefore, the researchers concluded that it is probable that the organizers did not stimulate either type of ability and that the small sample size may also have affected the results.

The researchers noted two factors that may have affected treatment fidelity: (a) students in both treatment groups engaged in extraneous notetaking, which could possible be considered as an additional generative activity and (b) many of the subjects in the PGO group did not complete the graphic organizer. The researchers felt that providing subjects with the graphic organizer electronically and allowing periodic opportunities to review and compare responses, may improve its effectiveness. This suggestion was based on Hawk, McLeod, and Jonassen's (1985) argument that graphic organizers be reviewed as instruction progresses and that the instructor check students' organizer misconceptions prior to any evaluation.

Another experimental study, Kenny (1992), which was a subsequent study to Kenny et al., (1991), compared the use of three instructional organizers—the advance organizer (AO), the participatory graphic organizer (POG), and the final form graphic organizer (FGO)—using a CBIV learning environment. The purpose of the study was to determine whether a less generative or more generative instructional organizer would be most effective in facilitating learning and retention in a hypermedia learning environment.

The study tested three hypotheses: (a) the PGO would be more effective than the AO and the FGO in enhancing immediate recall; (b) the PGO would be more effective than the AO and the FGO in enhancing retention; and (c) the AO and the FGO would not differ substantially in term of their effect on immediate recall or retention. This study included a control mechanism for extraneous notetaking, which was not controlled for in Kenny et al., (1991).

This study included 61 nursing students and faculty who were randomly assigned to three treatment groups. The CBIV program used a structured discovery approach in which the subjects were presented with a video sequence followed by a decision point. The subject matter was cardiac nursing. Subjects were given complete freedom to proceed through the program as they desired; however, they were asked not to take notes except where required by the PGO treatment. The subjects were given the first posttest (immediate recall) immediately after completing the program and were given the second posttest (retention) one week later. In addition, to the posttests, the subjects were asked to complete a one-page self report survey (i.e., Program Use Survey) to determine their use of such program options as the replay feature, library and glossary. In addition, time spent interacting with the program was measured and correlated with posttest scores, using Pearson r product moment coefficients. Also, one-third of the subjects in each treatment group were asked to participate in a semi-structured interview for the purpose of eliciting information on the participants' interactions with the CBIV and the instructional organizers.

An analysis of the results of the first posttest (immediate recall) showed that the PGO treatment group did not perform better than the AO or FGO groups. In fact, the PGO mean score (.18.05) was lower than the AO group (18.857). The difference was not statistically significant. In comparison to the FGO group's mean score (20.9), the PGO group scored significantly lower (18.05). This difference was statistically significant, $p \leq 0.05$.

Also, the results did not support the hypothesis that the use of a PGO would result in higher mean score than an AO or an FGO in terms of retention. The PGO treatment group scored significantly lower on the second posttest (16.7) than the AO group (18.52) and significantly lower (substantially) than the FGO group (19.4), $p \leq 0.01$.

Testing of Hypothesis 3—no difference between FGO group and the AO group in terms of immediate recall and retention—showed that the FGO group scored considerably higher (20.9) on the first posttest (immediate recall) than did the AO group (18.857). The difference was statistically significant, [$| 2.043 | < q_{.95}$ (3,86) = 2.0367. On the second posttest (retention), the FGO group again scored higher (19.4) than the AO group (18.524); however, the difference was not statistically significant. The researchers believed that the FGO possibly reduced learner confusion, disorientation, and cognitive overload by allowing the subjects to concentrate more on learning the material rather than learning to navigate through the CBIV program.

Analysis of the survey data indicated no statistically significant differences between the three instructional organizers. Also, there was no statistically significant difference among the three treatment groups in relation to time spent interacting with the CBIV program. However, an important finding was that all of the correlations except the FGO group on immediate recall were negative, indicating that those subjects who spent more time interacting with the program tended on an average to score lower on the posttests. The researchers did not discuss possible reasons for this finding.

An analysis of the interview data did reveal a number of trends:

- The guided discovery approach tended to be distracting and disorienting for most subjects.
- Most of the subjects felt that the AO organizer was irrelevant; however, they thought the FGO organizer was a useful orientation tool.
- Some subjects thought the PGO was useful on encoding information, while others found it distracting and would have preferred to alter its use to fit their own learning approach.
- A little more than half of the subjects found the restriction on notetaking to be an interference, while others stated it was not a problem.

The results of these two studies (Kenny, 1992; Kenny et al., 1991) mildly suggest that graphic organizers (i.e., PGO and FGO) could be effective tools in a hypermedia learning environment. Concerns generated from the studies were:

- Were the instructional organizers properly constructed to produce a subsumption effect? This has been identified as a concern in studies focusing on CBI (Kenny, 1993).
- Was the generative activity (PGO) actually generative and did the PGO constitute an additional activity in an already generative situation, thereby contributing to cognitive overload?
- What is the most effective underlying theories for predicting when instructional organizers will be most effective?
- What is the most effective method of notetaking procedure, structured or unstructured?

When visual illustrations are presented with text, knowledge acquisition can be facilitated; however, "the facilitative effects are not present across all situations" (Anglin, Towers, & Levie, 1996). Therefore, understanding the functional roles of visuals in providing instruction is very important. In their review of visual message design research, Anglin, Towers, and Levie (1996) argued that significant progress has been made in determining the effectiveness of static and automated graphics on learning; however, there are several deficiencies in this field of research: (a) research on static and animated graphics has not been continuous, but sporadic and fragmented, (b) animation research is very limited in scope, (c) researchers in instructional communication and technology have neglected to study memory models and theories of picture perception, and (d) research does not fully clarify the functional roles of visual in instructional materials. Therefore, research needs to continue to focus on how to effectively design visual messages and select research strategies carefully.

Park (1998) investigated the effects of two instructional strategies (i.e., visual display and contextual presentation) on the acquisition of electronic troubleshooting skills in a computer-based learning environment. In this study, Park used three different visual displays—animation (GA), static graphics (SG) and static graphics with motion cues (SGMC)--to represent structure functions, and troubleshooting procedures. Also, he used a context-dependent presentation (CDP) and a context-independent presentation (CIP) as a second independent variable. Park (1998) argued that there are still conflicting viewpoints concerning the value of context-dependent instruction in helping learners develop the intellectual ability needed to solve real-life problems.

This study was based on the assumption that "mental models are formed based on the perceived properties of the given situation"; therefore, context-dependent instruction will help form context-bound mental models (Park, 1998, p. 40). On the other hand, context independent instruction will facilitate the formation of task-based mental models independent of context. Park's (1998) hypothesis was that "context-dependent instruction would be more effective than context-independent instruction in solving problems" (p. 40).

This study was a reflection of the recent trend of investigating various instructional devices to determine their effectiveness in terms of knowledge acquisition, problem solving, and knowledge/skills transfer and was a follow-up to a previous study (Park & Hopkin, 1993). This study was designed to examine the special attributes of visual displays, especially those using automation. According to Park (1998), visual display research suggests that careful consideration be given to the use of the various visual displays because learning is only enhanced when attributes (e.g., motion) coincide with learning requirements of a given task. Another underlying assumption of this study was that animation could be used to facilitate understanding of dynamic concepts by helping learners visualize an objects movement, and also facilitate the understanding of a system's structure functions and similar troubleshooting procedures by helping learners form appropriate mental models (Park, 1998). It was also assumed that static graphics can accomplish similar results if they contain the cues needed to enhance a learners understanding of the system's dynamic functions and development of an appropriate mental model.

There were four dependent variables in this study: (a) number of trials needed to troubleshoot faulty electronic circuits that were structurally the same as the one used for instruction, in a performance test, (b) amount of time spend troubleshooting the faulty circuits in the performance test, (c) number of trials needed to troubleshoot faulty circuits that were structurally different from the one used for instruction, in a transfer test, and (d) amount of time spent troubleshooting the faulty circuits in the transfer test. Ninety-six undergraduate students participated in the study. The CBI developed to represent basic electronic principles consisted of three parts: (a) a tutorial lesson for teaching the basic concepts, structures, and function of electronic circuits, (b) a computer-based performance test consisting of eight simulated electronic troubleshooting problems that required learners to identify and fix faulty components in the same circuit as the one used for the tutorial, and (c) a computer-based transfer test consisting of 15 simulated electronic troubleshooting problems that required learners to identify and fix faulty components in 15 different circuits. The three levels of visual display were manipulated in the tutorial and performance test. The two levels of contextual presentation were manipulated only in the tutorial.

Initial results from the analysis of data did not indicate significant difference among the three treatments. However, the follow-up exploratory analysis indicated that animation was more effective than static graphics in troubleshooting complex problems in transfer situations, especially when static graphics do not adequately represent the dynamic nature of animation. There was no significant difference among the treatment groups on the performance test and on simple transfer problems. Effects of the contextual presentation strategies varied form different types of problems. The CDP treatment group required less time for troubleshooting faulty circuits on the performance test, where as the CIP treatment group was more effective on the transfer test in where each problem was presented in the context of a uniquely defined circuit. Park (1998) believed that these variations could be attributed to the different types of mental models learners formed during the training. The CDP group seems to have formed system-bound models, where as, the CIP group seem to have formed component-based mental models. The system bound mental models seem to be more efficient at helping learners identify faulty circuits; however, component-based mental models seemed to be more efficient in helping learners troubleshoot newly encountered faulty circuits.

Graphic Organizers and Concept Maps

Concept maps are text representations that identify relationships between concepts. Novak and Gowin (1984) defined concept maps as "a schematic device for representing a set of concept meanings embedded in a framework of propositions" (p. 15). Both concept maps, as well as graphic organizers, originated from Ausubel's Assimilation Theory that suggested "learning becomes more meaningful when it occurs in context with the learner's prior knowledge" (Jonassen, Beissner, & Yacci, 1993, p. 155). Both graphic organizers and concept maps can be used to represent, assess, acquire, and convey structural knowledge. These instructional support devices are used for both generative and supplantive instruction (Bromley, Irwin-De Vitis, & Modlo, 1995; Jonassen, Beissner, and Yacci, 1993; Katayama, Armbruter, Dubois, Groulx, Jonassen, Kiewra, & Winn, 1996; Smith & Ragan, 1993 ,1999).

Below are specific educational applications for concept maps derived from the literature:

1. determining the learner's prior knowledge—differences between experts and novices knowledge structures (Jonassen, Beissner, & Yacci, 1993; Novak & Gowin, 1984).
2. generating meaning from textbooks, laboratory/studio experiences, and/or field studies (Novak & Gowin, 1984).

3. encouraging creativity by helping learners identify novel relationships between concepts (Jonassen, Beissner, & Yacci, 1993).
4. developing an outline for a paper or exposition (Jonassen, Beissner, & Yacci, 1993; Novak & Gowin, 1984).
5. developing a curriculum or testing items (Jonassen, Beissner, & Yacci, 1993).
6. providing pre- or post- instructional summaries (Jonassen, Beissner, & Yacci, 1993).
7. orienting learners to specific learning outcomes (Novak & Gowin, 1984).
8. facilitating notetaking (Jonassen, Beissner, & Yacci, 1993; Novak & Gowin, 1984).

One important consideration for instructional designers should be what instructional support device is best suited for the learner, the task, and the learning context. Katayama et al., (1996) reported on two of three experiments that examined the effectiveness of adjunct displays, particularly researcher-constructed displays. Varying viewpoints as to the effectiveness of supplantive (teacher constructed) versus generative instruction still appears to be a major issue in learning research.

Experiment 1 involved 56 undergraduate educational psychology student, who were assigned to three different treatment groups (text only, text with concept map, and text with matrix graphic organizers). The topic of the text material was "Classroom Instruction and Evaluation;" the same version was used for all treatment groups. After the two-day study session, subjects were given a 24-question test, including 6 short answer, 2 multiple choice, 2 short essay, and 16 fill-in-the-blank items.

The results of the study revealed no significant main effect of study supplement type and no significant difference between the groups (text only vs. concept map or graphic organizer vs. concept map). The researchers concluded that evidence to support the assumption that learners given graphic organizers as a study supplement would score significantly higher than those given a concept map or text only was not found. The yielded mean score of the text only group (15.50) was the highest of the three treatment groups, graphic organizer group (15.60) and concept map group (13.75). Possible reasons for this contradictory finding were attributed to: (1) test construction bias and (2) test relativity.

Experiment 2 sought to address the issues of test construction problems identified in Experiment 1 by having an outside expert construct the test. Also, Experiment 2 added an additional dependent variable, length of testing.

Forty-six undergraduate educational psychology students participated in the study. The participants were randomly assigned to three treatment groups (same as Experiment 1). The new constructed text consisted of 43 multiple choice and short answer, 33 factual and 10 conceptual. The participants were also asked to fill out a questionnaire to assess their prior knowledge and their opinions toward the study materials. The questionnaire was not a part of Experiment 1. The two-day procedure was basically the same as Experiment 1 with the exception of study time allocated, Experiment 1 (45 minutes) and Experiment 2 (35 minutes).

The results of Experiment 2 indicated a significant difference for the graphic organizer group (M=19.53, SD = 6.51, $p < .05$) as compared to the text only group (M = 14.75, SD - 3.15, $p < .05$) and the concept map group (M = 16.40, SD = 2.56, $p < .05$) on factual items. On conceptual items, the graphic organizer group scored significantly higher (M = 5.93, SD = 1.94, $p < .05$) than the text only group (M = 4.00, SD = 1.83, $p < .05$) and marginally higher than the concept map group (M = 4.80, SD = 2.01, $p < .05$). Analysis of total scores between the three groups yielded a significantly higher score for graphic organizer group (M = 25.47, SD = 7.85, $p < .05$) than the text only group (M = 18.75, SD = 4.19, $p < .05$) and the concept map group (M = 21.20, SD = 2.93, $p < .05$).

From the results, the researcher concluded that the type of test constructed and by whom could influence learner performance. Also, they concluded that graphic organizers could significantly enhance learning; however, type of spatial display appears to be secondary to text construction in terms of designing instruction. Based on the results of Experiment 2, graphic organizers were more effective than concept maps in facilitating learning.

Previous research, which has primarily been in the field of reading, has not clearly proven the effectiveness of graphic organizers as instructional support tools, and in particular, their use as conceptual models. Even though studies such as, Sein and Bostrom (1989) and Bromage and Mayer(1981), did not identify the conceptual models used in their studies as graphic organizers, their description of the conceptual models were consistent with the characteristics of graphic organizers. The analogical model used by Sein and Bostrom included two graphic illustrations of a file cabinet (one with a drawer opened containing file folders) and a graphic illustration of a file folder with labeling). These graphic illustrations were used to show the analogous relationship of a file cabinet and folders to the target system, an electronic mail system. The abstract model was a hierarchical diagram of the structure of the electronic mail system. Both conceptual models were based on the theory of structure mapping, and graphic organizers are considered to be one of several ways to convey structural knowledge. Bromage and Mayer (1981) used verbal and pictorial analogies that emphasized concept principles as conceptual models in Experiment 2. These conceptual models provided subjects with explanations of camera operations and operational rules.

According to several studies (Driscoll, 1994; Jih & Reeves, 1992; Jonassen, 1997; Kieras & Boviar, 1984; Wilson & Rutherford, 1989), conceptual models facilitate learner performance because they: (a) help in the organization of new information, (b) help in problem-solving transfer, and (c) facilitate inferencing and reasoning which tends to enhance learning. Conceptual model research has been very instrumental in identifying specific design principles to be used in instructional situations. The following section discusses three experimental studies on the use of conceptual models to provide instructional support.

Conceptual Model Research

The following studies (Bromage & Mayer, 1981; Koubek, 1990; Sein & Bostrom, 1989) examined the effects of conceptual model provision on various types of learning tasks (e.g., problem-solving, recall, near and far transfer, knowledge representation, procedural learning) and learning style differences (e.g., visual ability).

Conceptual Models and Using VAX Mail. Sein and Bostrom (1989) conducted a study to examine the effects of two cognitive styles variables (i.e., visual ability and learning mode) in the formation of mental models of novice users of an electronic filing system. This electronic filing system is referred to in the study as VAX Mail. Two types of conceptual models were used in the study: abstract and analogical. The interactive effects of learning mode with visual ability effects were examined on near-transfer tasks and far-transfer tasks. Ekstrom, French, and Harman (1976) defined visual ability as "the ability to manipulate or transfer the image of spatial pattern into other arrangements" (cited in Sein & Bostrom, 1989). More specifically, it is a term used to describe a novice's ability "to construct a mental representation (i.e., mental model) and then 'run' it" (Sein & Bostrom, 1989, p. 206). Learning mode referred to the learner's preferred approaches to learning and the problem-solving process (e.g., concrete experience, abstract conceptualization, reflective observation, active experimentation) derived from Kolb's (1971) experiential theory of learning.

The study involved 104 undergraduate subjects who were enrolled in an introduction to computers course at a large university. These subjects had very little understanding of the operation of an electronic mail system. Two independent variable, full-factorial designs were used to analyze the data instead of a 2 x 2 x 2 factorial design because of cell size requirements:

- Conceptual Model x Visual Ability (Abstract or Analogical)
- Conceptual Model x Learning Mode (Abstract or Analogical).

The subjects were involved in several pre-treatment activities: consent forms, background questionnaire, and VZ-2 test—a paper folding test used to measure visual ability taken from the battery of cognitive factor-referenced tests developed by Ekstrom, French, & Harman, 1976). After the pre-treatment activities were conducted, conceptual models of two different formats (abstract and analogical/concrete) were distributed to the subjects based on their classification as "concrete" or "abstract" learners using norms set by Kolb's Learning Style Inventory. These conceptual models were used as advance organizers. In this study, conceptual model training simply means the provision of a conceptual model. After the conceptual model training, subjects were given a quiz in which they had to describe the system. This data provided the researchers with an initial assessment of the subjects' mental model representations of the system. Then, the subjects were given hands-on-training on the system followed by problem-solving tasks. Following the training session, a posttest was given in which the subjects were given a six-item short answer test and two additional questions which asked subjects to: (a) describe the mail system as they understood it and (b) explain the system as they would describe it to a novice user, using the "teach-back approach."

An analysis of the data generated the following results:

- To determine if there was any interaction effect between learning mode and visual ability, a Spearman correlational analysis was conducted and found to be nonsignificant.
- Conceptual model provision and visual ability appeared to have no interactive effects on near-transfer. Even though there was no significant interaction, subjects

classified as "high visuals" (i.e., those subjects scoring half a standard deviation above the mean on the VZ-2 test) scored significantly better than "low visual" (i.e., those subjects scoring half a standard deviation below the mean on the VZ-2 test), (4.71 vs. 3.90), $p = .003$.

• No visual ability and conceptual model type interactions were found on far-transfer tasks. However, those subjects classified as "high visuals" scored significantly better than "low visual" subjects, (1.33 vs .80), $p = .012$. Learner performance based on analogical treatment was approximately the same (i.e., 1.14 for the "high visuals" and 1.00 for the "low visuals.) An examination of cell means showed that "high visuals" performed better than "low visuals" (1.48 vs .57) based on abstract treatment.

• Results from the comprehension test showed no differences between the performance of the two conceptual model groups; however, "high visuals" performed significantly better than "low visuals", (36.96 vs 23.94), *p* not indicated. No interaction effect was found.

• To examine the interaction effects of conceptual model provision with learning mode (i.e., abstract and analogical) on near-transfer tasks, an ANCOVA was run using prior computer experience as the covariate. There was no conceptual model main effect or interactions found. However, abstract learners performed better than the concrete learner.

• An ANOVA run on learner performance in far-transfer tasks showed only a marginal difference between the performance of the abstract and analogical groups. There was a strong learning mode main effect. The subjects receiving the abstract treatment performed significantly better than the subjects receiving the analogical treatment (1.41 vs .087), $p = .012$.

• An examination of cell means on far transfer tasks did show a strong interaction (2.13 vs .76), p not indicated. When the subjects who were classified as "abstract learners" were given the abstract conceptual model, they scored almost three times higher than those subjects who received the analogical conceptual model. The pattern was reversed when the treatment was changed. When subjects who were classified as "analogical" learners received the analogical conceptual model, they scored twice as high as those given abstract conceptual models (1.15 vs .61).

• Results of the comprehension test showed no difference between the performance of abstract and analogical conceptual model groups. There was no interaction effect; however, the subjects classified as "abstract" learners scored better than those classified as analogical (concrete) learners (34.00 vs 26.95), $p = .06$.

Sein and Bostrom (1989) drew the following conclusion: (a) There were no conceptual model-type main effects for near or far transfer tasks; (b) Individual difference variables are important in the formation of mental models—"high visual " subjects performed better than "low visual" subjects on both near- and far-transfer tasks; and subjects given the abstract conceptual model performed better than whose given the analogical conceptual model; (c) The effectiveness of a conceptual model depends on the individual user characteristics interacting with conceptual model not on the type of conceptual model. Also, the stronger visual ability main effect, the learning mode main effect, and the interaction effect virtually washed out any conceptual model main effect.

Implications drawn from Sein and Bostrom (1989), as well as several previous studies (Bostrom, Olfman, & Sein, 1987; Carroll, Olson, & Anderson, 1987; Sein, Bostrom, & Olfman, 1987) were: (a) there is a need to tailor instructional supports to accommodate individual differences, (b) visual processing ability and learning mode preferences can be enhanced in individuals, and (c) conceptual model provision can help learners form more accurate mental models.

<u>Conceptual Models and Word Processing</u>. Koubek (1990) conducted a study to examine the effects of training (i.e., conceptual model provision) , problem representation (i.e., user's mental model) and individual differences on learner performances of both automated (simple) and controlled (complex) process tasks, while learning to use the word-processing program, (Microsoft Word version 4). An automated process task refers to a simple, straightforward task in which the cognitive processes needed to perform the task are usually automatic. A controlled process task refers to a complex problem-solving task where cognitive process are conscious, and a time limitation in terms of task completion may be instituted.

The study involved 19 undergraduate students who were from various academic backgrounds. The subjects had little or no general word processing experience and no prior experience working with Microsoft Word. The Hidden Figures Test was used to classify subjects as FD or FI. The subjects were trained to use the wordprocessor by one of two different presentation approaches: alphabetical or hierarchical. In the alphabetical training approach, the commands were arranged in alphabetical order; where as, with the hierarchical training approach, the commands were placed in an hierarchical order based on the interrelationships of the various functions. To evaluate knowledge representation of the subjects' word processing subject matter domain (i.e., users' mental models), subjects were asked to complete a representation evaluation form (i.e., mental model assessment) which included 17 learned word processing commands, paired with one another, yielding 136 items. Subjects were asked to rate the paired commands based on their degree of similarity using a 5-point Likert scale—"semantic distance" measure. The data were evaluated using clustering techniques to determine subjects' representations of the word-processing domain. The results from this analysis provided insight concerning the degree of accuracy and completeness of participants' mental representations. Participants representations were characterized by the following variables: (a) maximum distance between clusters, (b) total number of clusters, (c) number of horizontal layout commands misclassified, (d) number of vertical layout commands misclassified, (e) number of font commands misclassified, (f) purity of horizontal layout cluster, (g) purity of font cluster, (h) overall clarity purity, and (I) number of commands not clustered.

As a part of this study, subjects were asked to perform two editing tasks using the skills they had learned during the training. The first task required subjects to perform 30 centering tasks. This task was referred to as the "automated" process task, more specifically, the automatic cognitive processing of a task. In the second task, subjects were asked to place two paragraphs side-by-side in a document. The task included several steps, and the subjects were required to complete the task in 15 minutes. This task was referred to as the "controlled" process task that required the use of various conscious cognitive resources to complete the task.

Koubek (1990), who also examined the effects of conceptual model provision on learners' performance on problem solving task, argued that: (a) the method of training received and the learner's cognitive style dimension could significantly impact knowledge representation and task performance and (b) if individuals received extensive training in how to perform simple and complex tasks, their performance of such tasks would become automatic and thereby improve their performance time and efficiency. An analysis of the data, a 2 x 2 MANOVA, showed no main or interaction effects for training or cognitive style dimension on representation development. However, there was a significant interaction between method of training and cognitive style dimension on automated task performance, $F(1,15) = 7.04, p < .018$). Also, there was a significant interaction in terms of the learning rate (i.e., completion time) of the subjects, $F(1, 15) = 6.45, p < .023$. Field dependent subjects who received "alphabetic" training had a significantly higher learning rate than the other treatment groups (FD x hierarchical training, FI x alphabetical training, FI x hierarchical training) on automated tasks performance. The FD subjects who received hierarchical learning had the lowest learning rate on automated task performance.

Six of the 19 subjects were able to successfully complete the "controlled" process task in the time allotted. Due to the fact that only a small number of subjects completed the task, Chi Square procedures were used. Method of training and cognitive style dimension I had no significant effect on controlled task performance, Chi Square = .693, p < .405.

Additional analysis to determine the effects of task representation (i.e., developing a mental model of task procedures/requirements) on automated task performance indicated a significant correlation between mental model development and automated process task performance, Squared Canonical Correlation was 0.82, $p < .02$. Therefore, the results supported the argument that knowledge representation does affect learners' performances on automated task, at least in the beginning stages of acquiring automaticity.

To examine the effects of task representation on controlled task performance, the subjects were divided into two groups—successful or unsuccessful task completion. Those subjects completing the controlled process task in 15 minutes or less were classified as "successful," and those who failed to complete the task in the time allotted were classified as "unsuccessful." A Chi Square analysis using Overall Cluster Purity (i.e., knowledge representation variables) grouped 0-1 and 2-3 and successful/unsuccessful task completion showed a significant interaction, Chi Square = 6.094, $p < .025$. To determine the likelihood of predicting learners' performances on controlled process tasks based on these findings, a discriminant analysis was conducted on the 19 subjects. Use of the computed discriminant function with Overall Cluster Purity showed that there was a high degree of accuracy in terms of using the time element to classify subjects as "successful" or "unsuccessful." Eighty-nine percent of the subjects were classified correctly. Only four subjects were misclassified—one successful subject and three unsuccessful. This finding supported the hypothesis that knowledge representation significantly influences controlled task performance.

To analyze knowledge representation of the controlled process task (i.e., use of solution strategies), a GOMS (Goals Operators Methods and Selection) analysis was performed using verbal protocol data. This analysis was used to determine subjects' use of solution strategies. Based on the GOMS analysis, subjects were classified into three categories: *Direct*, *Single Branch*, and *Multiple Branch*. The *Direct* group described subjects whose solution path led directly toward task completion—no incorrect use of strategies. Four subjects were placed in this group. Five subjects were placed in the *Single Branch* group. These subjects tended to use a single solution path even though the path was not leading them toward task completion. Ten subjects were placed in the *Multiple Branch* group. The subjects placed in this category used several different methods to try to find the correct solution. Also, the subjects in this category could implement no more than two incorrect methods consecutively. The classification process was done by two independent raters.

To determine representation differences among the three groups, a Wilcoxson's Rank Sum Test was performed using Overall Cluster Purity. The results from the analysis showed that the *Direct* group performed better than the *Single Branch* group, $p < .05$, and the *Multiple Branch* group $p < .05$. These results were not significant. Another interesting finding was that 75 percent of the Direct group was able to complete the task as compared to the Single Branch group and Multiple Branch group, 0% and 30%

respectively, indicating that those subjects using a straightforward, error-free approach to the solution tend to complete the task in the time allowed.

The author drew the following conclusions:

- An important factor in learner performance on cognitive-oriented tasks is "domain representation."
- Knowledge representation of task requirements (i.e., mental model) influences performance on complex tasks, including the strategy used to complete them.
- There is no apparent difference in learners' problem-solving performances of based on the cognitive style dimension of FD/FI.

Koubek also felt that since computer-oriented task usually require both automated and controlled processes from system users, emphasis should be placed on selecting and reinforcing the correct representations for particular task requirements and individual learner characteristics.

Conceptual Model and Understanding Camera Mechanisms. Bromage and Mayer (1981) conducted a study which included two experiments which were designed to test the effects of a "concrete model" (i.e., conceptual model) on recall and problem-solving performance. The subject-matter content for both of the experiments was photography, more specifically how to operate a 35mm camera.

Experiment 1 was designed specifically to determine if there was a relationship between the types of information the subjects recalled from the passage and their performance in camera problem solving. *Experiment 1* did not include the provision of a conceptual model. Conceptual models were only used in *Experiment 2*. The study involved 26 students enrolled in a college introductory psychology course. None of the subjects had prior knowledge with using a 35mm camera.

The subjects were given a six-page passage booklet to read entitled "How to Use the Camera." Then they were given a cued recall test which consisted of eight essay questions that required subjects to address three different types of problem solving activities: (a) describe the adjustment of the camera in a specific problem situation, (b) indicate camera setting for a variety of situations based on the ideal of "designing a camera for children," and (c) indicate camera setting for a malfunctioning component.

Subjects were scored on five measures: (a) variables (the total number of inputs and outcome variables that a subject recalled when cued to do so), (b) "d relations" (number of times the subject gave a unique input variable that affected some outcome variable or vise versa), for example, describing how the shutter speed will affect whether the picture is over- or underexposed), (c) "e relations" (number of times the subject gave an internal variable that affected some outcome variable that was affected by some input variable), for example, turning the focus moves the film toward or away from the vertex of the image in the camera, (d) facts, and (e) problem solving (i.e., each problem was broken down into component parts that required a simple answer for which one point was given).

From an analysis of the data, Bromage and Mayer (1981) described the following results. There was a positive correlation between the problem-solving test and recall of "e relations" and recall of variables (e.g., sunlight, f-stop, and exposure which can influence the outcome), but all others correlations were nonsignificant. The results of several *t* tests indicated the correlation of .59 between problem solving and "e relations" was significantly greater than the correlation of .08 between problem solving and d relations, $t(23) = 2.70, p < .02$, and the correlation of .59 was not significantly different from the correlation of .30 between problem solving and facts, $t(23) = 1.52, p < .10$, and the correlation of .59 was not significantly different from the correlation of .56 between problem solving and recall of variables ($t < 1$). Therefore, the conclusion drawn was that "good" problem solving is related to recall of explanation of internal camera mechanisms (e relations) but not to description of rules (d relations), which are the relations among input and/or output variables.

To further examine the data, a principal components analysis was performed for similar characteristics among the measures. The results showed that good problem solving, recall of underlying mechanisms (e.g., stating that turning the focus move the film toward or away from the vertex of the image in the camera), and recall of facts (e.g., listing f-stop numbers) seemed to relate in this study; however, recall of description (e.g., stating that if the aperture is changed, you can compensate by changing the shutter speed) and recall of explanation (e.g., stating that if your f-stop is changed, there will be a smaller or larger hole for letting in light) did not relate. Also, an analysis (stepwise discriminant analysis) was performed to compare the low problem-solving and high problem-solving groups on four recall scores. Only "e relations" scores were found to be a discriminating factor between good and poor problemsolvers, a significant discrimination among the groups, $p < .05$. This led researchers to believe that the ability to recall underlying mechanisms seems to be the best way to distinguish between good problemsolvers and poor ones.

Lastly, an ANOVA was conducted to determine if there was a difference between good and poor problemsolvers in terms of recall. The analysis of the data showed that there were differences in the overall amount recalled by the three groups (i.e., high intermediate and low problem solving abilities), $p < .005$; and differences in type of test, $p < .001$; and interaction between group and type of test, $p < .05$. Further analysis of interaction was done by performing a Newman-Keuls test. That test produced the following results:

e relations—the high problem solving group recalled significantly more than the low problem solving group.

variables—there was no significant difference between the intermediate and high groups, whereas the low groups recalled less than the high and intermediate groups.

facts—the only significant difference obtained was between the low and intermediate problem-solving groups, for "d relations" no differences were significant.

A second ANOVA was conducted in an attempt to resolve the problem of using raw scores instead of standard scores. The second ANOVA which was performed with standard scores show a main effect for problem solving ability, $p < .001$, and the

Treatment X Recall Test (variables—facts, "e relations", "d relations") reached a marginal level of significance, $p < .075$.

A third ANOVA (one-way) was conducted to resolve the problem of scale difference among dependent measures using problem- solving group as the between-subject factor. The results indicated significant differences among the three groups (high, intermediate, low) on recall of e relations, recall of variables, and recall of facts, $p < .05$. There were no significant differences among the groups on recall of d relations. Bromage and Mayer (1981) felt that Experiment 1 clearly showed evidence that a definite relationship does exist between recall of explanation of mechanisms underlying camera operations (e relations) and creative solution of camera problems (problem solving).

Experiment 2 further explored the provision of a conceptual model. Two different passages were designed for this experiment. One of the passages was organized around explanation of mechanisms (e relations) which included verbal and pictorial analogies and emphasized concept principles. Bromage and Mayer (1981) classified the verbal and pictorial analogies used in this study as "concrete mechanical models" that provided explanations on camera operations. The other passage was organized around the description of operational rules (d relations). Both passages contained the same "d relations", facts, and variables but varied in terms of emphasis and organization of "e relations" (i.e., information about internal mechanisms). The primary purpose of this experiment was to determine whether a relationship exists between emphasis on explanation of mechanism and the learner's ability to engage in problem solving.

The subjects were taken from the same pool as in Experiment 1. As with Experiment 1, none of the subjects had experience with using a 35mm camera. Forty-five subjects were used in this experiment. Twenty-two subjects were assigned to a treatment group that was given the explanation of mechanisms passage to read (i.e., conceptual model); and 23 subjects were assigned to a treatment group that was given the description of operational rules passage to read. (See Appendix A for Description of Text Passages). All subjects were given the same posttests.

The problem-solving test was divided into two segments: near transfer test and far transfer test. The near-transfer test tested for specific relationships between the variables described in the text using the technical terms from the test (e.g., What would cause a picture to have a poor depth of field?). The far-transfer test described problem solving situations that required the subjects to solve the problem based on knowledge acquired from the text. The subjects were asked to respond to the same three problem-solving activities used in Experiment 1 to assess "far" transfer of knowledge (i.e., (a) describe the adjustment of the camera in a specific problem situation, (b) indicate camera setting for a variety of situations based on the ideal of "designing a camera for children," and (c) indicate camera setting for a malfunctioning component) in addition to four more types of "near" transfer problem-solving activities that required the subjects to (a) find the cause of a specific problem, (b) discover new relationships among variables, (c) identify which variables are relevant in a novel situation, and (d) construct new devices. The scoring of data was the same as that of Experiment 1, except for an additional measure for near transfer.

In testing the data for recall differences, an analysis of the data showed a significant effect due to treatment in which the explanation group, recalled more elements overall, $p < .05$; a main effect due to type of test (i.e., "e relations" cued recall test) in which the test produced different average scores and a significant interaction, $p < .001$. The interaction was consistent with the observation that predicted similar group scores for "d relations," facts, and variables but not in recall of "e relations". The results of t test revealed a significant difference between the "explanation group" and the "description group" with the explanation group producing more "e relations" than the description group, $t(43) = 9.04, p < .001$. Also, the explanation group recalled marginally more variables that the description group, $t(43) = 1.98, p = .05$.

An ANOVA was performed on recall scores using treatment group (i.e., explanation vs description) as a between-subjects factor and the six tests (i.e., variables, d relations, e relations, facts, near transfer, far transfer) as a within-subjects factor. The results indicated a main effect for treatment favoring the explanation group, $p < .01$ and a significant interaction between treatment and type of test, $p < .001$. Subjects receiving the passage with "e relations" scored significantly better on the cued recall tests than those subjects receiving the passage with no "e relations."

To test whether manipulating a critical feature in the passage (i.e., elaborating on concept principles) would facilitate far transfer, t tests were used. The analysis showed no significant differences in group mean scores on near transfer, $t(43) < 1$; however, the explanation group performed significantly better than the description group on far transfer (i.e., creative problem solving), $t(43) = 2.27, p < .05$. The results suggest that the use of conceptual models (i.e., concrete mechanical models) help facilitate learner performance on creative problem-solving tasks especially when there is an appropriate match between instructional treatment (i.e., method of presenting instructional material) and the type of instructional support used.

To determine which measures would be more accurate for identifying certain distinctions between the explanation and description groups, a stepwise discriminant analysis was performed using variables, “d relations”, facts, near-transfer problem solving, and far-transfer problem solving as dependent measures. The results indicated only one measure, far transfer, to be significant in distinguishing between groups, $p < .05$; a classification accuracy of 67 percent was reached which was considered to be significant at $p < .05$ based on a z test.

Bromage and Mayer (1981) concluded from their analysis of data that there is consistent evidence showing that when technical text is organized around underlying mechanisms, such as mapping the given variables and relations into a familiar concrete analogy or metaphor (i.e., conceptual models), creative problem solving can be enhanced. In support of Bromage and Mayer’s (1981) claim, Young (1983) argued that conceptual models can be used to provide instructional support to the learner and facilitate problem solving. His argument was centered around two types of conceptual models, *surrogate* and *mapping*. Young (1983) defined *surrogate* models as a “mechanistic” model of how a particular device/system works; this type of conceptual model provides information about the operation of the device/system. *Surrogate* models can be physical objects or written analogous statements and can be used as problem-solving facilitators by providing learners with a mental representation of the device/system (Young, 1983). *Mapping models*, sometimes referred to as "task/action models," can be defined as a conceptual model that describes the "core of mappings" (i.e., interface) that exist between the user and the target device/system (Young, 1983). According to Young (1983), the interface model acts as a "communication model," which links the task domain to the action domain. Most of Young's viewpoints were based on his earlier study (i.e., Young, 1981) in which he studied users' conceptual models of a pocket calculator.

Although Young (1983) appeared to be a strong advocate of conceptual model provision, he cautioned individuals who design instruction to be aware of various limitations certain conceptual models have, especially *surrogate* models. He believed that surrogate models have a limited range of applicability. Young (1983) argued that for basic problem-solving tasks that require the learner to simply generate a sequence of operations to achieve some desired outcome, the *surrogate* model can possibly be used to help the learner construct the appropriate mental representation. However for the performance-oriented tasks, the *surrogate* model seems to be of little help in facilitating performance because most surrogate models do not provide learners with enough detail knowledge about the internal workings of the device/system that are needed to help learners reason, troubleshoot, and make inferences about the behavior of the device/system (Young, 1983). Two other drawbacks Young (1983) mentioned briefly were: (a) some *surrogate* models fail to identify various salient features of a device/system, which can prohibit problem solving and (b) the internal mechanisms of a device/system may be too complex to illustrate using a *surrogate* model.

Due to the fact that surrogate models tend to focus on the device itself, giving no consideration to the user or task, Young (1983) felt that the *task/action mapping* model may be a better conceptual model than the *surrogate* model because it focuses on the relationship between the task to be performed and the user's behavior. Young argued that the distinction between the two models can be based on their position on a bipolar dimension in which *assimilation* is on one end and *accommodation* is on the opposite end. "Models at the assimilatory end tend to view the device in terms of its relationship to other systems already familiar to the user (e.g., strong analogy model). At the accommodatory end, the emphasis is more on understanding the device in its own right (Young, 1983, p. 51). The design aspects of both the surrogate model and the task/action mapping model seem to place them at the accommodatory end.

Several of the empirical studies reviewed in this paper (Land & Hannafin, 1997; Njoo & de Jong, 1993; Smith et al., 1997) tend to support the notion that providing learners with various kinds of instructional support (e.g., hints, orienting devices, advance organizers, etc.) based on such factors as learner characteristics, task requirements, and learning context, can enhance learners' problem-solving performances. More specifically, several studies (Bromage & Mayer, 1981; Kieras & Boviar, 1984; Koubek, 1990; Sein & Bostrom, 1989) support the provision of a conceptual model as a means of enhancing problem-solving performance. These authors proposed that conceptual model provision helps some learners build appropriate mental models, which can enhance their abilities to solve problems more effectively, especially in a particular subject-matter domain. The most often used conceptual models, according to the literature review, seem to be analogy/metaphor models and task/action models. They can be either verbal or visual, concrete or abstract. However, in order to assess appropriately the impact of conceptual model provision on learner performance, the learner's before- and after-mental model of the system or device must be known.

Norman (1983) and Sasse (1991) suggested several methods for measuring an individual's mental model before and after instructional treatment: (a) teach-back approach, (b) observation, (c) think alouds (verbal protocols) and (d) on-line protocols. Although these assessment tools have been used in a number of research studies, using more than one method seems to result in a more accurate measurement of learners' mental models.

Another focus of this study is how individual differences impact learning and problem-solving performance. For several decades, that argument has been that individual differences in abilities can affect how individuals learn and solve problems. It is believed that individuals differ in how they structure knowledge and use problem-solving strategies; therefore, the instruction should be adapted to meet the individual learner's needs. Therefore, this study examined the effects of conceptual model provision on FD and FI learners in a domain-specific, problem-solving tasks.

Role of Individual Differences in Designing Instruction

Learners differ in a wide variety of ways, and these differences are likely to influence how they react to and benefit from a particular instructional method or learning environment. For example, as reported in the previous section, Koubek (1990) found that the cognitive styles of FD and FI did appear to influence subjects' performances on an automated process task and task completion time. The instructional method and learning environment may either help or inhibit an individual's learning. Understanding the importance of individual differences is essential to the effective design and delivery of instruction. With greater understanding of individual differences, instruction can be appropriately adapted to accommodate the information processing strengths and weaknesses of various cognitive styles.

Cognitive Styles

Cognitive styles, also referenced to such terms as cognitive controls, information processing modes/habits, and cognitive strategies, are defined as individual variations in abilities to perceive, organize, process, remember, and utilize information while interacting with the environment (Green, 1985; Jonassen and Grabowski , 1993; Kogan, 1971; Messick, 1978). Jonassen and Grabowski (1993), differentiated between the terms "cognitive style" and "cognitive controls." They define cognitive style as the various ways in which individuals gather information (e.g., visual/haptic) or organize information, (e.g., serialist/holist). They define cognitive controls as "psychoanalytic entities" that control one's perception of environmental stimuli; cognitive controls describe pattern/processes of thinking (e.g., field dependence/field independence.)

Smith and Ragan's (1993) view of cognitive styles is that they are beneficial to instructional designers because they "provide information about individual differences from a cognitive and information processing standpoint. Information on cognitive styles can provide insight into not only whether an individual is likely to be able to perform well or poorly on a particular learning task but also why" (p. 47). They argued that "cognitive style measures are relevant only when considered with regard to a particular learning task" (p. 47). They used field dependent/field independent learners as an example of their argument. Because field dependent and field independent learners process information in different ways (i.e., the ability to disembed a detailed item from a more complex field) successful performance on tasks requiring the learner to disembed objects would, therefore, necessitate more instructional support for field dependent learners. Their argument was that when the learning task(s) is suitable for both field dependent and field independent learners, there would be very little or no difference in learning. After reviewing literature on cognitive styles, Ragan, Back, Stansel, L. Ausburn, F. Ausburn, Butler, and Huckabay (1979) concluded that the information processing modes of FD/FI learners do have distinct advantages under certain circumstances and have adaptive properties which hold implications for training and instruction.

Field Dependence/Field Independence

One of the most researched areas of cognitive styles is field dependence/field independence (FD/FI). The cognitive style of FD/FI describes the degree to which an individual perceives and comprehends information, globally or analytically (Jonassen & Grabowski, 1993; Kogan, 1971; Messick, 1978). FD/FI is often considered to be a prescriptive tool for learning and instructional outcomes (Jonassen & Grabowski, 1993; Witkin, 1979).

Herman A. Witkin (1950) is credited with the development of the field dependence/independence construct. In Witkin's (1950) investigation of perception of visual space he sought to determine the importance of visual cues in perceiving the vertical direction of space. Space orientation situations were used to assess what one perceives when bodily cues were in conflict with visual cues. He used a battery of tests (i.e., *Rod and Frame Test, Body Adjustment Test, Embedded Figures Test*) to examine self-consistency in perception. These tests measured an individual's tendency to rely on the visual field or the body itself as a source of cues for locating the upright. More specific information about these tests will be presented later in the paper.

From his investigations, Witkin (1962) concluded that each individual had his own preferred style of integrating information and that individuals tend to be self-consistent in performance which is predictable across situations. He categorized the individuals into two groups based on their performance: (a) those who had a tendency to see objects in their field of view as a single unit—termed "field dependent" and (b) those who had a tendency to see objects in their field of vision as separate units—termed "field independent." Witkin et al., (1977) referred to field dependence/independence as a cognitive style dimension, more specifically as bipolar dimensions with each dimension reflecting a different set of attributes. Social attributes are characteristics associated with field dependent individuals, where as, cognitive restructuring attributes are associated with field independent individuals (Davis, 1991; Korchin, 1986; Linn & Kyllonen, 1980; Witkin et al., 1977/1979).

Witkin et al., (1977/1979) argued that this concept of field dependence/ independence being bipolar in nature also points to the fact that these constructs have "adaptive value"; that is, neither construct is better or worse than the other, but both poles have qualities that help individuals adapt under certain circumstances. Witkin et al.,

(1977) felt that this concept of bipolar dimensions was very important because it distinguishes cognitive styles from intelligence and other ability dimensions in that abilities are value laden, that is, it is better to have more of it than less of it.

Attributes of FD/FI Learners

Cognitive learning research suggests several important implications for researchers concerned with the cognitive style dimension of FD/FI and its impact on the instructional design and educational practice. Several studies (Cooperman, 1980; Davis, 1991; Davis & Cochran, 1982; Davis & Frank, 1979; Goodenough, 1976; Korchin, 1986; Satterly, 1979; Witkin et al., 1974/1977) have researched the relationship of FD/FI to information processing capabilities and intelligence, as well as aspects of behavior (i.e., vocational and educational choices). For example, Davis and Frank (1979), Goodenough (1976), and Witkin et al., (1977) argued that FD and FI learners differ on a number of critical learning processes, such as, attending, encoding, organizing, analyzing, and memory processing. In addition, cognitive style research indicates that field dependent and field-independent individuals differ in their abilities restructure information in a perceptual and cognitive mode (Davis, 1991; Davis & Cochran, 1982; Jonassen & Grabowski, 1993; Witkin et al., 1977/1979).

Davis and Cochran's (1982) literature review led to the following conclusions concerning field dependent/independent individuals: (a) field-dependent individuals have difficulty attending to relevant cues particularly when distracting ones are present; (b) field-dependent individuals have difficulty processing large amounts of information; however, little or no differences were found between field-dependent and field-independent individuals when limited amounts of information had to be processed; and (c) field-independent individuals were able to recall information from long-term memory better than field-dependent individuals, and this superiority was probably related to organizing and structuring processes used when storing and retrieving information. According to Berger and Goldberg (1979), FI individuals appear to be more task oriented. FI individuals are better able to focus their attention on the specifics of a task than FD individuals.

Witkin et al., (1977) considered educational/vocational interests and choices as a function of the cognitive style dimension of FD/FI. FD individuals (i.e., interpersonal-oriented) tend to favor educational/vocational areas that involve social interaction; on the other hand, FI individuals (i.e., impersonal-oriented) tend to favor areas that provide a solitary work environment. Along the same line of thought, Korchin (1986) argued that since field independent individuals are better at segregating and manipulating abstract concepts, they tend to be drawn toward fields of mathematics and science, where as, field dependent individuals who are more people-minded, tend to be drawn to fields in the humanities, social sciences, and human-helping professions. So FD/FI has been described as both a narrow construct—ability to disembed figure from background—and a more global construct that includes preferences for social interaction.

Jonassen and Grabowski (1993), in their review of literature, differentiated instructional conditions that were more suitable for FD learners and for FI learners based on both narrow and broad interpretations. For example, instructional conditions that appear to be more suitable to the preferences of FD learners were: (a) a "social" learning environment, (b) deliberate structural support with salient cues, especially organizational cues such as advance organizers, (c) clear, explicit directions and the maximum amount of guidance, (d) orienting strategies before instruction and (e) extensive feedback (especially informative). As for FI learners, they suggested: (a) an independent learning environment, (b) inquiry and discovery instructional methods, (c) an abundance of content resources and reference material to sort through, (d) independent, contract-based self-instruction and (e) minimal guidance and direction. They proposed that by knowing which instructional conditions are more suitable for certain learning modes/preferences, the particular needs of the learners can be met by means of instructional support—adaptive instruction.

When engaged in problem-solving tasks or processing information from a new subject-matter domain, FD and FI individuals seem to use different strategies (Reiff, 1992). For example, FI individuals usually attempt to solve problems using an "analytical" cognitive approach in which they generate their own concept structure and hypotheses by means of analysis. On the other hand, FD individuals usually attempt to solve problems using a "global" cognitive approach in which they tend to rely external cues to help them represent concepts and generate solutions. In exploratory learning environments where cues may be tacit rather than salient, FD individuals' problem-solving performances may be inhibited. Also, a narrow visual processing construct is to induce principles from photos; and to do this, learners must be able to visually disembed salient features from photos. Therefore, adapting the level of instructional support based on individual differences in learning may prove to be very beneficial in enhancing the performance of learners. Before specific instructional support can be provided based on individual needs, particular learning modes/preferences/strategies should be identified.

Measuring Field Dependence/Field Independence

Various tests have been used to determine an individual's style of perceiving and processing information—FD or FI. Identified in Jonassen and Grabowski(1993) are seven different tests that are most commonly used to measure FD/FI:

Embedded Figures Test (EFT)--(Witkin, Oltman, & Karp, 1971)

Children's Embedded Figures Test (CEFT)--(Witkin, Oltman, & Karp, 1971)

Group Embedded Figures Test (GEFT)--(Witkin, Oltman, & Karp, 1971)

Hidden Figures Test (HFT)--(French, Ekstrom, & Price, 1963)

Closure Flexibility Test (Concealed Figures)--(Baehr, 1965)

Auditory Embedded Figures Test--(White, 1954)

Tactile Embedded Figures Test--(Axelrod & Cohen, 1961)

When choosing a method for measuring FD/FI, both reliability and correlational values should be considered. The Closure Flexibility test, claiming to measure FD/FI has not been validated, but is believed to require the same mental ability as the other tests and can be used as a possible alternative (Jonassen & Grabowski, 1993). In this study the GEFT will be used to classify subjects as FD or FI. A detailed description of the GEFT will be discussed in Chapter 3 and an example found in the Appendix.

Field Dependence/Field Independence and Intelligence

For many years, researchers have sought to establish a significant relationship between field dependence/independence and intelligence. This is because so many studies have found FI learners to out perform FD learners regardless of the type of instruction. Evidence from these studies has been inconsistent, thereby causing an ongoing controversy. Two studies (Cooperman, 1980; Witkin et al., 1977) found significant correlations between field dependence/independence and IQ. Cooperman (1980) conducted a study using 150 male and female college students. To measure intellectual ability, a rote learning task and a verbal learning task was administered. The rote learning task involved a group-administered test using paired-associate nonsense syllables. The Verbal Reasoning subtest of the Differential Aptitude Tests (DAT) was used to measure verbal reasoning. The results of the study showed that field independent groups had significantly higher scores than their counterparts on both rote learning and verbal reasoning tasks. On the group-paired associate learning tasks, mean scores were 252.93 for the FD group and 270.53 for the FI group, $p < .05$. On the verbal reasoning task, means were 15.03 for the FD group and 18.85 for the FI group, $p < .001$. Cooperman suggested that these results tend to support the position that cognitive style is a predictor of intelligence.

Witkin et al.(1977)) findings were similar to those of Cooperman (1980); however, he denied the importance of intellectual factors in the field dependence/ independence dimensions because he felt that the significant findings could possibly be attributed to the amount of perceptual and analytical tasks included in IQ tests. In other words, IQ tests by design appear to be more appropriate for FI learners, thus giving them an advantage over FD learners in terms of performance scores. Witkin (1976) argued that the cognitive of styles of field dependence/field independence should not be equated with general cognitive competencies or intelligence even though that dimension is considered to be an "ingredient of intellect."

Berger and Goldberger (1979) and Reiff (1992) also agree with Witkin that the construct of FD/FI is not enough to predict intelligence. Berger and Goldberger (1979) found no statistically significant correlation between the Rod Frame Test and scores from the vocabulary test ($r = .04$) or the Embedded Figures Test and scores from the vocabulary test ($r = .01$). Reiff (1992) argued that there is no difference in the intellectual abilities of field-dependent and field-independent individuals; however, FD and FI individuals do tend to differ in their abilities to process and use information. More specifically, FI individuals appear to be more flexible in the use of problem-solving strategies and the ways they learn new material (Reiff, 1992).

<u>FD/FI and Problem Solving Ability</u>

In regard to problem-solving abilities of FD/FI learners, Green (1985) reported that FI learners may have a larger number of strategies available to them and may be more willing to utilize novel approaches, or FI learners may be more efficient in recognizing when a solution strategy is not working. If Green's assumption is true, prompting FD learners as to appropriate strategies to use during instruction may enhance their performance.

Conflicting conclusions were drawn from studies conducted by MacNeil (1980), Haplin and Peterson (1986) and Kini (1993). MacNeil (1980) investigated the effects of two different instructional treatments, discovery and expository, on the change in learning performance of individuals of contrasting cognitive styles. The treatments were developed based on the sequence of instruction (i.e., bottom-up vs. top-down), degree of instructional guidance (i.e., high vs. low), and method of presentation (i.e., student centered vs. teacher generated). Thirty-two field-dependent and thirty-two field-independent undergraduate students were randomly assigned to one of nine experimental groups (three expository, three discovery and three no treatment). The Behavior Modification Achievement Test (BMAT) was used to measure change in learning performance. A test of gain scores indicated a significant difference between the discovery group ($M = 12.996$) and the control group ($M = 3.88$), $p < .05$, and between the expository group ($M = 15.908$) and the control group ($M = 3.88$), $p < .05$. An examination of the main effect of cognitive style on the BMAT test proved to be insignificant. There was also no significant interaction between the instructional style and cognitive style.

MacNeil (1980) attributed the lack of significant results to three possible explanations. The first possible explanation was that there may have been a problem with the design of the testing instrument—BMAT. That is, many of the questions on the test were classified as easy, and the type of questions which resulted in correct answers seem to facilitate guessing thereby possibly causing inflated scores. The second possible explanation for no significant difference in the findings was the subject matter content chosen for the experiment (i.e., behavior modification). The subject matter was considered to be "neutral" because it did not require a high degree of analytic ability nor did it attend to social cues. This assumption was based on Witkins's et al. (1977) argument that subject matter content can influence learning of FD/FI individuals. The final explanation for the lack of significant findings pertained to the matching/mismatching of cognitive style to instructional style. The three instructors used in the experiment were all classified as FD individuals which MacNeil felt might have put the FI individuals at a disadvantage based on the assumption that matching students with instructors having the same cognitive style enhances learning.

MacNeil (1980) concluded that based on the findings of his study, there appeared to be no difference in learning abilities of FD/FI learners, based on the specific conditions of the experiment. In addition, he stated that the most important factor in providing individualized instruction is "the identification of key variables unique to each learner (e.g., academic strengths and weaknesses, preferences and dislikes" (p. 358).

Haplin and Peterson (1986) conducted a study to determine whether there would be a significant interaction of problem-solving and analytical abilities of 221 graduate and undergraduate students using printed materials which were designed to match their particular cognitive styles. The GEFT (Group Embedded Figures Test) was used to measures cognitive style. Form A instruction was specifically designed for field-dependent subjects. This form included visual cues, much structure, opportunities for review and feedback and socially oriented examples of concepts. On the other hand, Form B instruction was designed specifically for field independent subjects. In Form B, concepts and explanations were concise and brief, visual cues were absent, and review material required the use of analytical and problem-solving abilities. The subjects were randomly assigned to either Form A or Form B. Multivariate and univariate analyses of variance where used to analyze the data. The results indicated no significant difference (p

< .05) in learning or attitudes between those subjects whose cognitive style matched the study material and those subjects whose cognitive styles were mismatched to study material.

More recently, Kini (1993) conducted a study to determine if there were any significant effects to matching certain learners' characteristics to different kinds of instructional treatments. More specifically, he examined: (a) the relationship between the cognitive style of FI/FD and the subjects preferred perceptual mode (i.e., verbal or visual) and (b) the main effects and interactive effects of FI/FD subjects on learning performance on a concept learning task based on two different presentations formats (i.e., text only and text plus animated graphics). FI subjects were expected to perform better than FD subjects irrespective of instructional treatment but especially under "text-only" conditions. Kini (1993) based his prediction on previous research that indicated FI individuals are usually better at "cognitive restructuring" than FD individuals. Also he investigated the time spent by the subjects on the two lesson formats—latency effect. Study time data included: (a) time spent on each individual frame and (b) total time spent in lesson.

The study involved 192 undergraduate students from a variety of academic disciplines. They participated in an introductory computer-delivered presentation of velocity and acceleration concepts. The GEFT was used to classify subjects as field independent or field dependent, and a verbalizer-visualizer questionnaire was used to identify subjects' preferences for verbal or visual presentation mode.

An analysis of the data generated the following conclusions:

- There was no significant main effect of cognitive style on concept learning.
- There was no significant interaction effect on the performance of individuals when the concepts were presented to match subjects' preferences of perceptual mode and presentation format, for example, verbal learners matched with text-only presentation and visual learners matched with text plus animated graphics.
- The results show that those subjects who received the lesson presentation format containing text and graphics seemed to spend less time in the lesson than those subjects who received the lesson presentation containing only text.

Some of the aforementioned studies reported that field-independent students' performances were better than field-dependent students regardless of the instructional treatment, while others reported no significant difference. Others reported no significant difference when the learning task or instructional treatment is conducive to students' learning preferences. A preponderance of the research reviewed in this paper seems to suggest that FD/FI learners differ in perceptual abilities (i.e., disembedding an element from its surroundings), cognitive abilities (i.e., representing, reorganizing, and restructuring information), and social skills. However, the degree of successful performance appears not to be related to a particular cognitive style but on how instruction is adapted based on additional factors such as learning task and learning context. For example, when solving problem learners or trying to comprehend new material, learners employ different strategies that can help or inhibit their performances. Also, the design features of hypermedia-based learning environments may also influence performance. For example, those individuals who tend to rely on external support for understanding new material and solving problems (i.e., FD individuals), may experience difficulty.

FD/FI and Hypermedia-Based Learning Environments

Recent trends have shifted from simply wanting to identify the major differences between the two cognitive styles to investigating ways to adapt instruction to meet the different learning patterns of FD/I learners. For example, studies have been conducted on (a) FD/I and navigation styles in hypermedia environments (e.g., Boyce, 1999) and (b) FD/I and learning strategies in hypermedia environments (e.g., Leader & Klein, 1994; Summerville, 1998; Liu & Reed, 1994; Hsu, Frederick, & Chung, 1994). These studies also reflect a trend toward investigating the learning performance of FD/I learners using various designs of hypermedia learning environments.

Boyce (1999) investigated the effects of FD/I on learner performance, learner completion rate, sense of "becoming lost," and navigation style. The hypertext-based learning environment was created by using a continuing professional education instructional model delivered via the WWW. Participants' cognitive styles were determined using the Hidden Figures Test. Post-lesson and post module examinations were used to measure learner performance scores. Completion rates were determined by completion or non-completion of the post-lesson and post module examinations. A six-item participant feedback survey was used to measure sense of "becoming lost," and classification of navigational style was based on patters used by participants when visiting lesson content pages.

Hypothesis One, which expected to find no difference in FD/I learners in terms of performance scores from module quizzes was rejected. FI learners scored significantly higher at the $p = 0.0055$ level than FD learners on Quiz 3, $p = 0.0019$, Quiz 4, $p = 0.0003$, and Quiz 7, $p = 0.004$. A 70 percent passing score was the basis for the rejection

Hypothesis Two, which expected to find no difference in FD/I learners in terms of completion rates was not rejected. Completion rates were equivalent for both cognitive styles. The researcher believed that this finding supports the assumption that WebCT is navigable for both cognitive styles.

Hypothesis Three, which expected to find no difference in FD/I learners as to sense of "becoming lost,' was not rejected. Actually, FI learners indicated a higher rate of "becoming lost" than FD learners, which was in contradiction to some previous research studies.

Hypothesis Four, which expected to find no difference in FD/I learners in navigational styles (jump, linear, and toggle) was not rejected. The result of this finding was attributed to the assumption that when access to multiple navigational tools are made available (e.g., WebCT), similar performance between FD and FI learners is found.

Boyce (1999) suggested that careful consideration be given to web-based instructional design tools such as, WebCT, because of its ability to deliver as well as track learner performance.

Along this same line of research, Summerville (1998) conducted a study to examine several variables--achievement, satisfaction, and role of awareness--which might impact FD/I learners engaged in a hypermedia learning environment. This study also sought to identify any possible interaction of the variables: awareness of cognitive style, FD/I, and match/mismatch in a hypermedia environment. The basic assumption of this research was that hypermedia-based learning environments can be designed to support the various learning needs of both FD and FI learners. Another assumption is that FI learners would possibly perform better in hypermedia-based learning environments because FI learners appear to have more developed metacognitive skills. However, research has revealed conflicting evidence.

The participants in this study were 177 students enrolled in instructional courses. The cognitive style of the FD/I was determined using the Group Embedded Figures Test. A computer-based instructional program (including two different HyperCard stacks) was developed to teach HyperCard to the participants. Minimal instruction support was provided in the HyperCard stack created to accommodate the cognitive style of FI learners (generative environment); extensive instructional support was provided in the HyperCard stack, which was created to accommodate FD learners (supplantive).

Analysis of Matching/Mismatching. Upon analyzing the data to determine what effects matching and mismatching cognitive style with the two learning environments had on achievement and satisfaction in learning HyperCard, no significant difference was found, $F\,(2,164) = .0669, p < .05$.

Analysis of Role Awareness. Upon analyzing the data to determine what effect role of awareness had on FD and FI learners' achievement and satisfaction scores, no significant difference was found, $F\,(2,164) = .0971, p < .05$. These findings support evidence found in previous research (Hsu et al., 1994) that indicated the role awareness (knowing ones cognitive abilities) has no impact on learner performance. However, this finding was in contradiction to Lin's (1993) finding.

Analysis of Interactions. An analysis of the data to identify any possible interactions among the three variables (FD/FI, matched/mismatched, aware/unaware) based on achievement and satisfaction scores indicated no significant difference (FI/FD x MA/MS, AW/UW x MA/MS, FI/FD x AW/UW x MA/MS,).

Analysis of Qualitative Data. Qualitative data was obtained from the satisfaction questionnaire and from post-treatment interviews. An analysis of the data yielded the following information:

1. Several FD participants indicated a desire to have extensive instructional support with more step-by-step instructions.
2. Several participants who were mismatched with their instructional environment indicated they were confused and frustrated. This finding supports the assumption that learners be matched with accommodating learning environments.
3. Some participants in the FD/AW/MS group questioned why their treatment did not include more support and directions; the FD/UW/MS group blamed themselves for their failure. However, the FI/AW/MS group thought the instruction was too easy and the step-by-step instruction was annoying. These subjects had a tendency to blame external sources for their perceived lack of success. Also, these subjects too very few if any

notes even when told the information was important for helping them perform the required task (creating a HyperCard stack).

The researchers concluded that the qualitative data seemed to be more beneficial in this study than the quantitative data, and suggest that more qualitative studies be conducted in the areas of (a) use of a more scaffold hypermedia learning environment based on instructional design principles, and (b) adding a third category to FD/FI--Field Mixed (FM), for example in Meng and Patty, 1991. The FM category would include those subjects whose scores fall 1/2 standard deviation from the mean.

Based on the review of literature pertaining to individual differences and learning performance, several authors (Green, 1983; Jonassen & Grabowski, 1993; Smith & Ragan, 1993) tend to agree that individual differences in perceptual and cognitive abilities can possibly influence learning; and to optimize the learning experience, instruction needs to be designed to accommodate the particular needs of the learner. Boyce (1999) found significant findings between FD an FI learners in a hypermedia-based learning environment. On the other hand, there were several of the studies (Haplin & Peterson, 1986; Kini, 1993; MacNeil, Smith et al., 1997) examining the impact of various learner characteristics on learning performance where the results indicated no significant difference; nevertheless, these authors seem to agree that the role of individual difference in designing instruction is an important one. Because of the prevailing inconsistencies in the research, this study sought to examine the employment of cognitive style measures to help identify learners with specific instructional needs and select instructional material and strategies that are appropriate for particular types of learners and learning tasks and thus provide evidence of support to these various assumptions relating to FD/FI learners.

Influences on Problem-Solving Performance

Research on how to enhance problem-solving skills is still a major trend. Research investigations have focused on such areas as: (a) expert's vs. novice's problem solving, (b) well-structured vs. ill-structured problem-solving domains, (c) impact of various technologies and learning environments on problem solving, and (d) use of cognitive strategies in problem solving situations. This section discusses: (a) Instructional Design Implications for Problem Solving and (b) Problem-Solving Research.

Instructional Design Implications for Problem Solving

According to Jonassen (1997) and Smith and Ragan (1993), problem solving requires a variety of cognitive components such as, domain knowledge, structural knowledge, metacognitive skills, motivational/attitudinal components, and knowledge about self. Problem solving effectiveness depends on how well the learner understands and represents the problem type, including problem state and goal state (Jonassen, 1997; Voss, Lawrence, & Engle, 1991). In order for learners to accurately understand and represent the problem type, they must have conceptual and procedural knowledge of the subject matter domain. These two factors are essential to the problem solving process, in that, conceptual knowledge helps in the identification of the problem state, and procedural knowledge provides the mechanisms to problem solution (Hegarty, 1991).

Problem-solving experience (i.e., domain-specific knowledge) seems to be another factor that greatly influences problem-solving performance. Some researchers (Bryson, Berieter, Scardamalia, & Joram, 1991; Jonassen, Beissner, & Yacci, 1993; Smith & Ragan, 1993) contend that one of the major differences between the problem solving performance of experts and novices can be attributed to domain-specific knowledge, also known as "problem schemata." Experts because of their extensive problem schemata, are able to identify immediately the problem type and them apply previously learned procedures to the identified problem type (Bryson, et al., 1991; Jonassen, 1997). On the other hand, novices, who have somewhat deficient problem schemata, tend to rely on general problem-solving strategies. According to Hegarty (1991), "the problem schemata that is retrieved in any particular case is a crucial determinant of how the problem is solved because it determines what conceptual knowledge is used to elaborate the problem statement and what procedures are used to solve the problem" (p. 255).

Selection of the problem-solving strategies seems to be another factor influencing problem solving performance. Smith & Ragan (1993) and Jonassen (1997) identified several generic strategies used in problem solving: (a) means-to-end analysis (working forward), (b) recall analogy, (c) difference reduction, and (d) working backward. Novices tend to employ a working backward strategy, where as experts tend to employ a means-to-end strategy (Bryson, et al., 1991; Smith & Ragan, 1993), which seems to be a more effective problem solving strategy.

Instructional designing having knowledge of the factors that influence problem solving performance and considering those factor when designing problem solving instruction could possibly result in learning environments that are more suited to problem solving learning.

Jonassen (1997) presented an instructional design model for well-structured problems. The purpose of this model is to provide guidance in designing instruction to support problem-solving skill development. The process involves six steps:

1. Review prerequisite component concepts, rules and principles.
2. Present conceptual or causal model of problem domain. Conceptual models represent domain knowledge, while causal models more closely represent the solution process.
3. Model problem solving performance in worked examples.
4. Present practice problems.
5. Support the search for solutions.

   Provide problem-solving scaffolds such as, prompts/hints, problem diagrams, worked examples, analogical problems, and concept maps. Also provide adequate feedback about the learner's attempts to solve the problem.
6. Reflect on problem state and problem solution.

Jonassen's (1997) instructional design model is similar to the "Instructional Events for Problem-Solving Lesson" proposed by Smith and Ragan (1993):

1. Deploy attention.
2. Establish instructional purpose.
3. Promote interest and motivation.
4. Preview lesson.
5. Review relevant.

6. Help learner process information—presenting the problem, problem space, and appropriate rules.
7. Help learner focus attention.
8. Encourage learner to employ strategies.
9. Provide practice.
10. Provide feedback.

Problem-Solving Research

Wang, Young, Barab, and Gan (1999) conducted two experiments to examine the effects of goal intentions on problem solving and reading comprehension in a generative hypertext processing. The subject matter of the hypertext instructional program was "Nigeria." In Experiment One, 43 undergraduate students were assigned to one of four treatment groups: (a) linear format only, (b) linear and generative format, (c) navigational format only, and (d) navigational and generative format. The dependent measure for Experiment One was problem-solving success based on questionnaire responses (problem solving). The dependent measure for Experiment Two was reading comprehension scores and "dwell time." The same four treatments and instructional lesson were used. The participants were instructed to learn information in preparation for a set reading comprehension questions, instead of watching a video clip, which was used in Experiment One.

The results of Experiment One revealed that there was a significant difference between the two navigational activities (linear vs. navigation). Subjects in the navigational group outperformed the linear group with respect to problem solving score, $p < .001$.

There was no significant difference between generative and nongenerative conditions; however, there was a significant interaction among the navigational activities and generative activities, $p < .05$, which indicated that generative activities may inhibit learners when given more freedom to navigate to solve a problem.

The results of Experiment Two indicated significant difference between the generative group and the non-generative group. The generative group performed better on reading comprehension. There was no significant difference between the navigational group and the linear group. The linear group outperformed the navigational group based on reading comprehension raw score and dwell time; however, this effect was cancelled by dwell time in the final analysis—conversion of reading comprehension scores into efficient score (raw score/dwell time).

Wang et al., (1999) drew the following conclusions: (a) more freedom to navigate in hypertext environments may inhibit some learners' abilities to solve problems and (b) learners may adopt unclear problem solving goals that interfere with the problem solving process. Because learners may adopt different learning goals, teachers should inform learners of desired goals (Gagné, 1985; Smith & Ragan (1993).

Problem solving research continues to be an area of great focus in educational and non-educational settings. Research continues to provide information on (a) how to design problem solving instruction, (b) what strategies seem to be most effective, (c) how various learning environments impact problem solving performance, and (d) how much instructional support should be given to learners engaged in a problem solving activity. In spite of the amount of research already conducted, more research is need concerning this complex skill.

CHAPTER SUMMARY AND CONCLUSIONS

As evidenced in the literature, a common educational practice incorporated by many researchers has been to adopt an aptitude treatment interaction approach to designing instructional treatments that are thought to be differentially effective for field-dependent and field-independent learners. Instructional treatments are usually designed to complement the learning characteristics of both preferences for learning (Davis, 1991).

The purpose of this chapter was to review the literature on the use of conceptual models as instructional support devices and cognitive style dimension of field dependence/independence as predictor of information processing habits and the effect both of these variables have on learners' performances on various learning tasks and different types of instructional treatments. The purpose of this chapter was also to identify a theoretical framework on which to base the study. The literature has shown that: (a) the field dependence/independence concept has a theoretical base (i.e., information processing theory; (b) cognitive styles do not differ appreciably in learning aptitude or memory but may differ a great deal in the manner or procedure in which cognitive functions are performed, more specifically, the processing of information; (c) there are reliable and valid instruments for measuring FD/FI (i.e., EFT, BAT, RFT, GEFT, etc.); and (d) the design features of different types of learning environments may necessitate providing particular types of learners with specific instructional support in order to enhance their learning capabilities. Njoo and de Jong (1993) found some significant effects in their study on providing instructional support to learners engaged in computer-based, exploratory learning that lead them to conclude that providing learners with instructional support measures (e.g., hypotheses) that particularly train learners to use exploratory skills could possibly improve their performance. Also testing the effects of providing instruction support (i.e., orienting techniques) on certain learner characteristics and problem solving performance in a highly computer-based, exploratory learning environment, Smith et al. (1997) found wide variations in performance; however, the variations could not be significantly linked to variations of orienting techniques on learner characteristics nor did they find any significant interaction between orienting and learner variable on learning performance. They did conclude from this study that it is possible to create learning environments that are too generative, which could inhibit learning performance.

To further provide additional empirical evidence in this area of research, this study sought to examine the effects of conceptual model and cognitive style on problem solving abilities of learners engaged in a highly computer-based, exploratory learning environment. The learning environment (created by a computer-based simulation) provided very little instructional support.

CHAPTER 3

METHODOLOGY

This study examined the effects of conceptual model support and cognitive style dimension (i.e., FD/FI) on mental model development and problem solving performance in a low-instructional support, exploratory learning environment. The following questions were examined:

1. Does the provision of a conceptual model influence domain-specific problem solving?
2. Does the provision of a conceptual model differentially affect problem solving performance of FD versus FI learners?
3. Does conceptual model provision and FD/FI influence length of engagement with instructional material in an exploratory learning environment?

In addition, this study investigated "what effects prior experience with photography, computer playfulness, and interest in photography have on problem solving of FD/FI learners?"

Participants for the Study

Seventy undergraduate students (38 males and 32 females) volunteered to participate in this study. The participants were enrolled in one of six different business class; they were from a cross-section of disciplines, grade classifications, and cultural backgrounds. Approximately one-third of the population was made up of international students. Participants were expected to have a basic knowledge of how to operate a computer. Nine of the subjects did not complete the study. This subject mortality resulted in a sample size of 61.

The subjects were classified as either FD or FI based on their performance on the GEFT. Those subjects scoring 0 to 9 were classified as FD (N = 22), and those scoring 10 to 18 were classified as FI (N = 39). The participants received extra credit point for participating in the study.

Materials for the Study

The materials for this study included instructional materials, testing instruments, and survey instruments.

Instructional Materials

The instructional materials used in this study were a conceptual model and a photography simulator. The learners in the conceptual model treatment received a conceptual model. The conceptual model was a graphic organizer that visually portrayed the relationship of aperture to depth of field. An expert in photography helped the researcher design the conceptual model and revise the photography simulation using Macromedia Director 7. The computer-based simulator—adapted from previous studies by Rezabek (1994), Smith et al. (1997) and Wedman and Smith (1989)--consists of one computer-based simulation depicting photos illustrating various degrees of exposure, depth of field, and motion/blur. The only learning guidance provided in this low-instructional support, exploratory learning environment is in the form of: (a) learning goals/purposes and (b) a conceptual model that was administered to certain treatment groups.

Testing Instruments

The testing instruments included: Group Embedded Figures Test (GEFT), Pretest/Posttest on Photography (Posttest 1), and Constructed Response Posttest (Posttest 2).

Group Embedded Figures Test. One of the most often used measurements of FD/FI is the Group Embedded Figures Test (Wooldridge, 1995). The GEFT consists of 25 complex test figures plus two sample figures. The test consists of three sections of 7, 9 and 9 test items. The first section is for practice only. The subjects are tested for their ability to find a simple figure embedded in a more complex design and outline it. The eight simple forms are printed on the back of the test booklet. The subjects are allowed to look at the simple figures as many times as they feel necessary. The scoring is done by visually comparing the outlined figure with a special scoring key. Scores on the GEFT range from 0-18. A high score on the GEFT is considered to be an indicator of FI, and a low score is considered to be an indicator of FD.

The GEFT is acceptably reliable (r = .82) (Witkin et al.,1991), and is highly correlated with the Embedded Figures Test (EFT) (r = .63 - .82) (Witkin et al., 1991), and the Hidden Figures Test (HFT) (r = .67 - .88) (French, Ekstrom, & Price, 1963). Reliability statistics were taken from Jonassen & Grabowski (1993)

Pretest/Posttest on Photography. The pretest and posttest consists of a 15-item multiple choice test which is designed to assess the participant's prior knowledge of the application of concepts and principles of photography. The pretest is an abstract assessment of principle application and combined application of principles. The posttest evaluates the same objectives. Adapted from Rezabek's Pretest on r = .74

Constructed Response Test. The Constructed Response Test is a 4-item test requiring problem-based, content specific principle application (domain-specific problem solving) with explanation of reasoning. Interrater Reliability = .88

Assessment Instruments

This study used four different assessment instruments: Interest in Photography Survey, Photography Experience Survey, Computer Playfulness Questionnaire, and Length of Engagement with the Photography Simulation.

Interest in Photography Survey. The Interest in Photography Survey (developed by Rezabek) included 16 Likert-scale questions used to gather information for the purpose of assessing the participant's attitude toward photography prior to instructional treatment.

Photography Experience Survey. The Photography Experience Survey (developed by Rezabek) included two questions for the purpose of identifying the participant's level of experience prior to instructional treatment.

Computer Playfulness Scale. A Computer Playfulness Questionnaire (developed by Smith and Ragan) will be used to gather information regarding the participant's attitude toward playful interaction with the computer, $r = .86$. According to Rieber (1992), inductive activities—learning activities that require learners to induce rules for themselves—"require an attitude of playfulness and exploration which older children and adults may resist," therefore, "adults should be properly oriented to assure them that the activity has a purpose" (p. 101). Analyzing the data collected from this survey instrument may provide some empirical support for Rieber's (1992) argument.

Length of Engagement with Photography Simulation. Data was collected via Director programming that records time data.

Research Design

The design of this study was a pretest/posttest control group design. Two independent variables were used in this study: (a) conceptual model provision/nonconceptual model provision and (b) cognitive style characteristic (i.e., FD/FI). The dependent variables were: (a) posttest scores--Posttest 1 and Posttest 2 and (b) length of engagement with instructional materials.

Procedures

The procedures were reviewed and approved by the Institutional Review Boards at the University of Oklahoma and The University of Central Oklahoma. Fifteen orientation sessions (Session 1) were held. During these sessions, subjects were given a brief explanation of the purpose of this study and were asked to sign the consent form. Next, the Pretest on Photography Principles, the GEFT, the Computer Playfulness Scale, the Interest in Photography, and the Photography Experience Survey were administered to the participants. Subjects were then asked to sign up for a second session (Session 2) to be held the following week. Between Session 1 and Session 2, subjects were classified as FD or FI based on their GEFT scores. Subjects were then randomly assigned to the four treatment groups. Stratified random sampling will be used to insure that both field dependent and field independent participants are in the control and experimental groups.

Thirteen Session 2s were held. Subjects were given individual folders with directions as to how to proceed with the experiment based on their treatment groups. Those subjects in the conceptual model treatment groups were given a conceptual model and instructed to study it prior to interacting with the photography simulation. The subjects in the control groups were instructed to immediately begin the photography simulation. The subjects presented with the conceptual model were allowed to retain it and refer to it as they interacted with the simulation. All subjects were told to spend as much time as they needed exploring the photography simulation to understand the photography principles demonstrated in the simulation by changing camera settings and taking a picture to see the results of that setting. No operating instructions or additional information were given during their engagement with the simulation.

After the different instructional treatments have been administered (i.e., conceptual model provision and the photography simulation) the subjects were given two posttests (Posttest 1 and Posttest 2). Upon finishing the photography simulation, the length of subject's engagement was recorded.

Null Hypotheses

Three different hypotheses will be tested in this study:

H_0 Provision of a conceptual model will not enhance the domain-specific problem solving performance of learners.

H_0 There will be no differential impact of conceptual model provision on domain-specific problem solving, based on cognitive styles of FD/FI learners.

H_0 There will be no differential impact of conceptual model provision on length of engagement with the photography simulation, based on cognitive styles of FD/FI learners.

In addition, exploratory data analysis was be conducted to determine "What effects do computer playfulness, interest in photography, and photography experience have on problem solving performance and length of engagement of FD/FI learners?"

Data Analysis

Several data analysis procedures were run using SPSS Version 10.0 for Windows. Descriptive analysis included: mean scores, standard deviations, and ranges for each variable. (See Tables 1 & 2) Inferential analysis was done using several statistical tests. To test the first hypotheses, *t*-tests on dependent variables were performed. To test the second and third hypotheses, several univariate analysis of variance were performed. In addition, several multiple regression analysis was used to determine how much variance of dependent measures could be attributed to secondary factors, such as, prior knowledge, interest in photography and photography experience, computer playfulness, and length of engagement with photography simulation. Below is a list of variables and their symbols.

Variable	Variable Symbol
Treatment Classification	TREATMENT
Group Embedded Figures Test Scores	GEFT
FD/FI Classification	FD_FI
Photography Pretest	PRETEST
Photography Posttest	POSTTEST 1

Constructed Response Test	POSTTEST 2
Length of Engagement	TIME
Interest in Photography	INTEREST
Photography Experience	EXPERIENCE
Computer Playfulness	PLAYFULNESS

Expected Results

There are three major expectations of this study. First, the main effects of conceptual model provision and nonconceptual model provision on problem solving performance were investigated. To solve problems in a complex domain, learners must have appropriate mental models. Previous research tends to suggest that some learners, especially novice ones, can be helped in the development of a more accurate mental model by providing them with a conceptual model. Subjects presented with a conceptual model were expected to perform better than those subjects not presented with a conceptual model.

Second, the main effect and interactive effects of FD/FI on problem solving performance were investigated in the context of the two treatment groups (conceptual model provision/nonconceptual model provision). Prior research suggests that when engaged in problem-solving tasks, explanatory learning, or processing information from a new subject matter domain, FI learners generally perform better than FD learners because FI learners usually generate their own concept structure and solution, where as FD learners usually rely on external cues to help them represent concepts and generate solutions. Therefore, those subjects identified as FD learners were expected to perform better in the conceptual model treatment group. On the other hand, those subjects identified as FI learners were expected to perform better in the nonconceptual model treatment group.

Third, the main effects and interactive effects of FD/FI and conceptual model provision/ nonconceptual model provision on length of engagement with instructional materials were investigated. Length of engagement with instructional materials seems to affect some learners' problem-solving performance, especially in exploratory learning environments. FD subjects who have been given a conceptual model (i.e., graphic organizer) were expected to spend more time with the computer-based photography simulation and perform better on problem-solving tasks, than those FD subjects who did not receive the conceptual model. FI subjects who have been given a conceptual model (i.e., graphic organizer) were expected to spend more time interacting with the computer-based photography simulation than the nontreatment subjects; however, there would be no difference in performance scores on problem solving tasks.

CHAPTER IV

RESULTS

Seventy students (38 males and 32 females) volunteered to participate in this study. The participants were enrolled in one of six different business classes. Nine of the subjects did not complete the study. This subject mortality resulted in a sample size of 61.

One of the purposes of this study was to investigate the effects of learning style characteristic (FD/FI) on problem solving performance. More specifically, this study sought to determine if any differential effects on learning could be attributed to the information processing styles of FD and FI. Therefore, the 61 subjects were classified as either FD or FI based on their performance on the GEFT. Those subjects scoring 0 to 9 were classified as FD (N = 22), and those subjects scoring 10 to 18 were classified as FI (N = 39).

In addition to investigating the effects of learning style characteristics on problem solving performance, this study investigated the effects of conceptual model provision (CMP) on problem solving performance as well. A 2 (CMP/NCMP) by 2 (FD/FI) factorial design was used resulting in the following division of subjects into four cells-- FD/FI were assigned to the control and experimental groups by stratified randomization. See Figure 1.

	FD	FI
CMP (Experimental)	10	21
NCMP (Control)	12	18

Figure 1. Design of the Study

Descriptive Statistics

Data were analyzed using SPSS Version 10.0 for Windows. Mean scores, standard deviations, and ranges for *GEFT*, *Pretest*, *Posttest* 1, *Posttest* 2 (*Transfer*), and *Time* are shown in Table 1, not respective of treatment groups. Table 1 shows that subjects (N = 61) scored higher on Posttest 1 than on the Pretest, thus indicating some degree of learning possibly occurred.

Table 2 shows descriptive statistics for three other factors investigated in this study—interest in photography (*Interest*), photography experience (*Experience*), and computer playfulness (*Playfulness*). These factors were used in the exploratory data analysis. Descriptive statistics showed high variance in student scores in the categories of *Interest* and *Playfulness*.

Inferential Statistics

A series of analyses were employed to investigate the data based on the three research questions for this study and to further explore the data. The first research question was: Does conceptual model provision influence domain specific problem solving? The purpose of this question was to determine if providing subjects with a

Table 1

Descriptive Statistics for Dependent and Independent Variables
(Variable, Sample Size, Mean, Standard Deviation, Minimum, and Maximum)

Variable	N	M	SD	Min.	Max.
GEFT	61	10.25	4.56	0	18
Pretest	61	6.00	2.25	1	11
Posttest 1	61	8.18	2.11	4	13
Posttest 2 (Transfer)	61	1.89	1.59	0	7
Time	61	7.44	4.06	.65	20.47

Table 2

Descriptive Statistics for Exploratory Factors
(Interest, Experience, and Playfulness)

Variable	N	M	SD	Min.	Max.
Interest	61	29.62	9.83	8	49
Experience	61	4.93	1.17	2	9
Playfulness	61	42.36	6.58	22	56

conceptual model could positively affect their problem solving performance in a highly exploratory learning environment. *T*-tests on dependent variables were performed to determine whether scores of those provided with the conceptual model (CMP) were significantly different from the control group (NCMP). The results revealed no statistically significant difference ($p < .05$). Figure 2 shows mean scores.

	Posttest 1	Posttest 2
CMP (Experimental)	8.35	2.00
NCMP (Control)	8.00	1.77

Figure 2. *t*-test Mean Scores for Posttest 1 and Posttest 2

gain score (*DIF*) was calculated as the difference between Posttest 1 and Pretest. When seeking to determine the effect of an independent variable on a dependent variable(s), a measurement of change in subjects' scores—from pretest to posttest–is an important aspect of experimental design. There was no significant difference ($p < .05$), NCMP (M = 1.97) and CMP (M = 2.39). Although the differences were not statistically significant, subjects in the experimental groups did score slightly higher on Posttest 1 and Posttest 2 than the subjects in the control groups; the power value was .77 (Cohen, 1977). Table 3 shows the group statistics of *t*-tests performed on Posttest 1, Posttest 2, and DIF variables.

The second research question for this study was: Does conceptual model provision differentially affect problem solving performance of FD versus FI subjects?

Four univariate analyses of variance were used to investigate the main effects and interaction effects of CMP on problem solving performance (*Posttest 1*, *Posttest 1* with *Pretest* as a covariate, *DIF*, and *Posttest 2*). For *Posttest 1*, the main effect of *Treatment* was not significant (p =.751), while *FD/FI* was significant (p = .025). The interaction of *Treatment* and *FD/FI* was not significant (p = .598). See Figure 3 for *Treatment x FD/FI* mean scores and Table 4 for results of univariate analysis. When *Pretest* was added as a covariate, *Treatment* remained not significant (p = .752), and *FD/FI* remained significant (p = .033). The interaction of *Treatment* and *FD/FI* remained not significant (p = .617). See Table 5 for results of univariate analysis. The results of the third univariate analysis of variance using *DIF* scores revealed no significant main effects for *DIF* regarding *Treatment* (p = .061) nor FD/FI (p = .052). These results also indicated no significant interaction effect for *Treatment* x *FD/FI*, (p = .962). See Table 6 for results of univariate analysis. The last univariate analysis of variance used *Posttest 2* scores and revealed no significant main effects for T*reatment* (p = .933) and *FD/FI* (p = .933). The results also indicated no significant interaction effect for *Treatment x FD/FI*, (p = .105). See Table 7 for results of univariate analysis.

	Posttest 1	Posttest 2
CMP (Experimental)	7.30	8.86
NCMP (Control)	7.42	8.39

Figure 3. Mean Scores for Treatment x FD/FI

Table 3

t-test Results for Posttest 1, Posttest 2, and DIF (gain scores)

Variable	Treatment	N	M	SD	SEM
Posttest 1	Control	30	8.00	2.03	.37
Posttest 1	Experimental	31	8.35	2.20	.39
Posttest 2	Control	30	1.77	1.65	.30
Posttest 2	Experimental	31	2.00	1.55	.28
DIF	Control	30	1.97	3.07	.56
DIF	Experimental	31	2.39	2.83	.51

Table 4

Univariate Analysis of Variance for Posttest 1
(Treatment, FD_FI, and Treatment x FD_FI)

Source	df	F	Sig.
Treatment	1	.102	.751
FD_FI	1	5.262	.025*
Treatment x FD_FI	1	.281	.598
S within-group			
Error	57	(4.243)	

Note. Value enclosed in parenthesis represent mean square error. S = Subjects
*p < .05

Table 5

Univariate Analysis of Variance for Posttest 1
(Treatment, FD_FI, and Treatment x FD_FI with Pretest as Covariate)

Source	df	F	Sig.
Pretest	1	.097	.756
Treatment	1	.109	.742
FD_FI	1	4.787	.033*
Treatment x FD_FI	1	.253	.617
S within-group			
Error	56	(4.312)	

Note. Value enclosed in parenthesis represents mean square error. S = Subjects.
*p < .05

Table 6

Univariate Analysis of Variance for DIF (Posttest 1 – Pretest)
(Treatment, FD_FI, and Treatment x FD_FI)

Source	df	F	Sig.
Treatment	1	.242	.625
FD_FI	1	.331	.567
Treatment x FD_FI	1	.002	.962
S within-group			
Error	57	(9.005)	

Note. Value enclosed in parenthesis represents mean square error. S = Subjects
p = .05

Table 7

Univariate Analysis of Variance for Posttest 2
(Treatment, FD_FI, and Treatment x FD_FI)

Source	df	F	Sig.
Treatment	1	.007	.933
FD_FI	1	.007	.933
Treatment x FD_FI	1	2.717	.105
S within-group			
Error	57	(2.535)	

Note. Value enclosed in parenthesis represents mean square error. S = Subjects
$p = .05$

A univariate analysis of variance using *Time* as the dependent variable revealed no significant main effect for *Treatment*, ($p = .534$), nor for *FD/FI*, ($p = .679$) The analysis also revealed no significant interaction effect for *Treatment x FD/FI*, ($p = .779$). See Table 8 for results of univariate analysis.

Table 8

Univariate Analysis of Variance for Time
(Treatment, FD_FI, and Treatment x FD_FI)

Source	df	F	Sig.
Treatment	1	.392	.534
FD_FI	1	.173	.679
Treatment x FD_FI	1	.079	.779
S within-group			
Error	57	(17.140)	

Note. Values enclosed in parenthesis represents mean square error. S = Subjects
$p = .05$

Additional Data Analysis

One could safely assume that prior knowledge would be one factor which would have an impact on problem solving performance; however, one could also possibly assume that several other factors such as, interest in photography, photography experience, and computer playfulness could impact problem solving performance. In order to test these assumptions, several stepwise multiple regression analyses were run to determine how much variance in the scores on *Posttest 1*, *Posttest 2*, *Time, and DIF* can be accounted for by *Interest*, *Experience*, and *Playfulness* scores. The regression formula used was

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + E.$$

where

y = predicted Posttest 1 score, Posttest 2 score, Time, and DIF score

β_0 = y intercept

$\beta_{1\text{-}5}$ = regression coefficients

X_1 = interest

X_2 = experience

X_3 = playfulness

Three regression analyses were used to determine the influence of Interest, Experience, and Playfulness on *Posttest1, Posttest 2, Time, and DIF (gain scores)*. No significant predictors were found for any of the dependent variables. See Tables 9 through 12 for results of regression analyses.

Table 9

Summary of Multiple Regression Analysis for Posttest 1

Variable	B	SE B	β	Sig.
Model 1				
(Constant)	6.928	2.300		
Interest	-3.100E-02	.031	-.144	.324
Experience	4.262E-03	.264	.022	.987
Playfulness	5.074E-02	.043	.158	.240

*$p < .05$
$R = .212$
$R^2 = .045$

Table 10

Summary of Multiple Regression Analysis for Posttest 2

Variable	B	SE B	β	Sig.
Model 1				
(Constant)	.126	1.746		
Interest	2.517E-02	.024	.155	.292
Experience	7.089E-03	.201	.005	.972
Playfulness	2.310E-02	.032	.095	.479

*$p < .05$
$R = .185$
$R^2 = .034$

Table 11

Summary of Multiple Regression Analysis for Time

Variable	B	SE B	β	Sig.
Model 1				
(Constant)	8.438	4.484		
Interest	-2.958E-02	.061	-.072	.628
Experience	-.292	.515	-.084	.574
Playfulness	3.112E-02	.083	.050	.710

*p = < .01
R = .143
$R^2 = .021$

Table 12

Summary of Multiple Regression Analysis for DIF (gain scores)

Variable	B	SE B	β	Sig.
Model 1				
(Constant)	1.178	3.250		
Interest	-4.109E-02	.044	-1.37	.355
Experience	.231	.374	.092	.539
Playfulness	2.551E-02	.060	.057	.674

*p < .05
R = .136
$R^2 = .019$

CHAPTER V

SUMMARY, DISCUSSION, CONCLUSIONS, LIMITATIONS AND IMPLICATIONS FOR FUTURE RESEARCH

Summary

Research studies on the effectiveness of different types of instructional support devices, such as conceptual models and concept maps, and on how these devices interact with different learner characteristics are still considered to be of great importance to instructional designers and educators. With the rapid development of new learning environments, especially exploratory/discovery/open learning environments, designing appropriate instruction becomes even more of a challenge. The purpose of this study was to provide some additional evidence to support these areas of research. More specifically, the purpose of this study was to investigate the effectiveness of conceptual model provision and learner characteristic, field dependence/field independence (FD/FI), on problem solving performance in an exploratory learning environment. In addition, the study sought to determine if length of engagement with a computer-based learning experience (simulation on photography principles) influenced problem-solving performance of FD and FI subjects.

A sample of 61 college students was used to test the hypotheses. The subjects were assigned to four different treatment groups: conceptual model provision (CMP) x field dependence (FD), CMP x field independence (FI), nonconceptual model provision (NCMP) x FD, and NCMP x FI. Subjects in the experimental groups were given a conceptual model in the form of an advance organizer, which presented a few basic photography principles related to exposure, depth of field, and motion/blur. Both experimental groups and control groups interacted with the computer-based simulation on photography principles. This low-instructional support computer-based simulation was used to create an exploratory learning environment.

Discussion of Findings

A pretest, two posttests, and time spent engaged with the simulation were used as dependent variables to investigate the impact of the treatment (conceptual model provision) and learner characteristic (*FD/FI*) on problem solving performance. The Pretest and Posttest 1 were 15-item objective tests designed to measure subjects' knowledge concerning photography principles. Posttest 2 was a four-item test designed to measure subjects' problem solving abilities to transfer learned principles by means of application.

The first hypothesis that predicted provision of a conceptual model would have enhance problem solving performance was not supported. The results revealed no significant difference among the experimental groups (CMP) and the control groups (NCMP) and; therefore, the null hypothesis failed to be rejected. More specifically, providing subjects with a graphic organizer depicting basic photography principles prior to their engagement with the simulation did not enhance problem-solving performance as measured by *Posttest 1* and *Posttest 2* mean scores. Although the difference was not statistically significant, subjects in the experimental groups did score higher than the subjects in the control groups on *Posttest 1* (immediate recall) and *Posttest 2* (transfer), $p < .05$.

One major reason for not finding a significant effect for CMP could be the small sample size. Small sample sizes can influence the outcome of hypothesis testing in addition to not providing a true representation of the population mean and standard deviation. A second reason for lack of significant findings could be to the ineffectiveness of the advance organizer (conceptual model). For example, if the advance organizer does not provide an assimilation environment or facilitate the active integration of new information, the advance organizer may not be useful (Mayer, 1979). Basic assumptions are that for conceptual models to be effective, they should be: (a) easy to understand, (b) match the target system, and (c) assist learners in processing information—acquiring, integrating, and structuring knowledge. Conceptual model design may even be more critical in well-defined subject matter domains such as photography, where there are few solutions and/or solution paths. Failure to meet specific design requirement may result in the ineffectiveness of an instructional support device.

Whether the learner is an expert or a novice can also impact the effectiveness of the advance organizer. For experts, who have developed strategies to use during learning, the conceptual model may not be very effective, but for novices it may be an effective tool. According to the descriptive statistics, most of the subjects ranked themselves as having a moderate amount of photography experience.

Furthermore, for the advance organizer to be effective, learners must recognize its importance as a learning tool. For example, the researcher observed that some of the subjects in the control group spent very little time studying the advance organizer prior to engaging with the computer-based simulation. One possible solution to lack of interaction with the advance organizer is to require subjects to spend a certain amount of time studying it. Jonassen (1993) proposed that giving the learner processing instructions that provide detailed instructions on how to use the organizer might also be beneficial to some learners.

Along this same line of thought, the degree of subject participation required by the advance organizer might have impacted the findings. A more generative (rather an expository) advance organizer may have been more beneficial to certain learners. For example, some learners tend to benefit from advance organizers that promote generative learning (participatory organizers) and others tend to benefit from advance organizers that promote supplantive learning (final form organizers). Previous research (Hawk, McLeod, Jonassen, 1985; Kenny, Grabowski, Middlemiss, & Van Neste-Kenny, 1991; Smith and Ragan, 1993 &1999; Spiegel & Barufaldi, 1994) supported the idea that participatory organizers seem to be more effective at facilitating student learning than final form organizers, especially in the areas of immediate recall, retention, and transfer.

Another consideration would be the requirements of the learning task. Assimilation theory argues that an advance organizer will enhance the acquisition of conceptual ideas but will not technical details; therefore, advance organizers should be more effective on transfer problems that require the application of general concepts (Mayer, 1979). In this study, for subjects to be able to solve problems effectively, they would need to have acquired or initially possessed conceptual as well as technical knowledge of photography principles. This study provided evidence that provision of a conceptual model, in itself, may not enhance learning because there are other factors that can confound the effects, thus indicating a need for further research.

The second hypothesis predicting no differential impact of conceptual model provision would be found on problem solving performance of FD or FI subjects was not rejected. Expectations were that FD subjects receiving the conceptual model would perform better those FD subjects not receiving the conceptual model, and that FI subjects receiving the conceptual model would perform better than FI subjects not receiving the conceptual model. An analysis of the findings indicated no significant main effect of *Treatment* on *Posttest 1*; however, *FD/FI* was significant ($p = .025$). A test for interaction effect did not achieve significance. When *Pretest* was added as a covariate, the results remained the same. Additional analysis on *DIF* (gain scores) and *Posttest 2* (transfer) revealed no significant difference.

Findings related to the second hypothesis indicated that FI subjects scored significantly higher than FD subjects, which was consistent with the findings of a previous study conducted by Davis and Cochran (1982). These findings are also consistent with Jonassen and Grabowski's (1993) viewpoint that FI subjects generally perform better than FD subjects in learning environments where they are allowed to generate their own concept structure and solutions, where as FD subjects usually rely on external cues to help represent concepts and generate solutions. The computer-based simulation used in this study was highly exploratory (low-instructional support), which may have caused FD subjects to become disoriented or experience cognitive overload and simply give up on trying to learn from the instructional program.

The third hypothesis predicted no interaction effects among conceptual model provision, FD/FI, or length of engagement with the photography simulation. Expectations were that FD and FI subjects who were given the conceptual model would spend more time engaging with the computer-based simulation and that FD subjects in the experimental group would perform better on problem solving tasks than FD subjects in the control groups. The results for interaction effect indicated no significant differences, thus the null hypothesis failed to be rejected. The results may have been affected by the variability of time of engagement (.65 to 20.47 minutes). Findings of no difference were consistent with Hsu and Chung (1994), Kenny (1992), and Kini (1994), and Summerfield (1988), which investigated the latency effect of various instructional tools on the learning performance of FD/FI subjects. Even though time did not have a significant effect on learner performance, Kenny (1992) reported finding differences among learner characteristic. FI subjects spent more time engaging with the computer simulation than FD subjects. This finding tends to support the assumption that highly exploratory learning environments are more conducive to FI learners. Lui and Reed's (1994) study found that control groups spent more time engaging with a computer-based instruction than did the experimental groups, which was contrary to the assumption that providing subjects with a conceptual model would result in their spending more time engaging with the instructional material. Based on these finding, it is apparent that more research is needed using time as a dependent variable.

To further investigate significant findings generated by previous analysis and to search for additional findings that could possibly be attributed to information gathered from the survey instruments (Interest in Photography, Photography Experience, and Computer Playfulness), several regression analyses were conducted. The results from the analyses indicated no significant predictors *for Posttest 1, Posttest 2, Time, and DIF (gain scores).*

In analyzing the results of this study, one should also consider what impact general ability possibly had on the findings, especially as it relates to field dependence/field independence research. Cooperman (1980) and Witkin et al., (1977) found significant correlations between FD/FI and IQ. However, Berger and Goldberger (1979) and Reiff (1992) do not support these finding. Those who support the notion that there is a high correlation between field independence and intelligence, suggest that if the treatment does not specifically draw upon or support field dependent characteristics, field independent subjects will be expected to perform better. Since there is still conflicting evidence on the relationship between field independence and intelligence, this factor cannot be ignored when analyzing the findings.

Conclusions

Evidence did not statistically support the assumption that conceptual model provision can enhance learning. However, subjects in the experimental groups mean scores were higher than subjects in the control groups. The degree of learner performance was influenced by learner characteristic. For example, FD/FI was found to be a significant factor on Posttest 1 (Recognition Test) but not on Posttest 2 (Problem Solving). Therefore, cognitive style and possibly the type of learning task seem to influence performance. The lack of significant findings for conceptual model provision and length of engagement with photography simulation could have been attributed to a number of factors such as small sample size, the design of the instructional support device, learner characteristic, learning task, and learning environment. In addition, the lack of significant findings suggest the need for additional research that considers factors such as learner attitudes and attributes (e.g., motivation, scholastic ability, interest in subject-matter content, prior knowledge), learning tasks, and time spent engaging with instructional materials.

Limitations of the Study

These results are specific to the sample population used in this study--undergraduate students from a cross-section of disciplines, grade classifications, and cultural backgrounds. Approximately one-third of the sample population was made up of international students.

Limitations to this study include:

1. Small Sample Size. The number of subjects in two of the four treatment cells was rather small (10 & 12). According to Cohen (1977,1988), for a power of .80, an effect size of .40, and an alpha level of .05, the appropriate cell size for each treatment should be 21. It should be noted that effect size varies according to the statistical test used.

2. GEFT Classification Procedures. Subjects were classified as FD or FI using the split-halves method, which included all participants. Other studies have used different classification methods that classify

subjects into three different categories--field dependent, field mixed (intermediate), and field independent.

3. Correlation of FI Subjects with General Ability. This study did not take into consideration the possible relationship between general ability and field independence, which could have confounded the results.

4. Subject-Matter Content. Photography can be classified as a well-defined subject-matter domain that requires learners to have some domain specific learning strategies for problem-solving situations. The results of this study may have been different for an ill-defined subject matter domain such as, mathematics, where there are more correct solutions and general problem-solving strategies may have been applicable.

5. Learning Task. This study limited its investigation to the measuring of effects of treatment on problem solving performance.

6. Quantitative Research Methods Only. The data collected for this study was acquired by quantitative methods of research and did not include qualitative data, which can be very helpful in providing insight about subjects' behaviors and attitudes.

Implications for Future Research

There are several follow-up studies suggested by these findings. First, the question of whether the conceptual model used in this study was an appropriate instructional device (considering design elements and subject-matter content) for the learning task required. A study comparing different types of advance organizers might be beneficial. Assessing learners' mental models before and after conceptual model provision might also be a way of evaluating the effectiveness of the conceptual model on cognitive structuring and learning.

A second follow-up study could examine the affective domain of learning by investigating the influence of interest and intrinsic motivation on learner performance. Smith and Ragan (1999) identified these two factors as being critical to the learning process. There are a number of measurement techniques that can be used to determine one's interest and motivational levels.

A third follow-up study could involve the validation of the GEFT as the best indicator of FD/FI as compared to the Hidden Figures Test (HFT) and the Portable Rod-and-Frame Test (PRFT).

Since time spent engaging with the photography simulation was revealed as being a significant predictor of Posttest 2 (transfer) performance, a study examining the effects of length of engagement on different learning outcomes, for example near transfer versus far transfer, might contribute to latency effects research.

There have not been very many qualitative studies done in this area; therefore, a study including a qualitative component would be beneficial. Acquiring data from verbal or on-line protocols and exit interviews could provide more feedback about learners' behaviors, attitudes, and problems as they engage with instructional support materials (e.g., conceptual models, concept maps, learning goals) and different types of learning environments.

Finally, one could development a treatment which embodies a factor such as a conceptual model, for which there is reason to believe its effectiveness, and then conduct research with that treatment to assist understanding for whom it works best under what conditions.

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APPENDIX A

DESCRIPTION OF CAMERA PASSAGES

Explanation-of-Mechanism Text

The explanation of mechanism text was entitled "Principles Underlying the Operation of the 35mm Camera," and consisted of approximately 1,700 words typed onto eight pages. This text was organized around "e" relations, with verbal and pictorial analogies presented. The passage was divided into four sections as follows: (a) The first section, "The Photographic Process," discussed the concept of an "image" on the film inside the camera; (b) The second section, "Creating an Image," explained the concepts of image focus (i.e., focusing the subject onto the film) and depth of focus (i.e., focusing the background onto the film) in terms of rays of light in the camera; (c) The third section, "Creating the Negative," presented the concepts of image brightness (i.e., exposure of film to light), film reactivity (i.e., particle-density of film), and motion (movement of image across film) in terms of amount and length of time that light is allowed to enter the camera and the nature of the film; and (d) The final section, "Taking the Picture," listed the steps in taking a picture that had been related to underlying mechanisms in the previous sections.

Description-of-Rules Text

The description-of-rules text consisted of approximately 800 words typed onto three pages. The passage entitled, "How to Use the 35mm Camera," listed five steps—select film, adjust lens, set f-stop, set shutter, and check shutter—and described how each influenced the final picture. The description text contained exactly the same facts and same description of rules (i.e., "d" relations) as the explanation text but contained no information about internal mechanisms (i.e., "e" relations).