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STUDENT PERCEPTIONS OF PROBLEMS' STRUCTUREDNESS, COMPLEXITY, SITUATEDNESS, AND INFORMATION RICHENSS AND THEIR EFFECTS ON PROBLEM-SOLVING PERFORMANCE

By

YOUNGMIN LEE

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The members of the Committee approve the Dissertation of Youngmin Lee defended on Aug, 25, 2004.

Marcy P. Driscoll
Professor Directing Dissertation

Neil H. Charness
Outside Committee Member

Richard L. Tate
Committee Member

Allan C. Jeong
Committee Member

Approved:

Frances A. Prevatt, Chair, Department of Educational Psychology and Learning Systems

The Office of Graduate Studies has verified and approved the above named committee members.

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ABSTRACT

The purpose of the present study was to investigate the effect of problem characteristics in terms of perceived structuredness, complexity, situatedness, and information richness on mathematical problem-solving performance. Structural Equation Modeling (SEM) was used to analyze the effects of problem characteristics obtained from subjects' ratings of their perception on their problem-solving performance. Three research questions were examined: 1) How are mathematical word problems perceived by problem solvers in terms of their' structuredness, complexity, situatedness, and information richness; 2) How do the perceived structuredness, complexity, situatedness, and information richness of problems relate to mathematical problem-solving performance; and 3) How do the perceived structuredness, complexity, situatedness, and information richness of problems relate to each other.

The descriptive data showed that traditional word problems in school were perceived as somewhat well-structured and information-rich, but also somewhat decontextualized and simple. The SEM analysis showed the following results. First, learners' perception of structuredness and situatedness had a positive effect on successful problem solving performance. That is, the more structured problems are perceived by students, the more likely they are to solve the problems without difficulties. In addition, the attempt to actively engage problem solvers in social and cultural environments to complete successful problem solving is led by situatedness.

Second, perception of information richness had no direct effect on problem solving-performance. Too much information may confuse problem solvers in choosing useful information required for problem solving, as well as cause problem solvers to fail to solve the problem finally. Third, learners' perception of complexity had a negative effect on successful problem solving performance. This result showed that the more complex the problem is, the less successful problem solvers are to solve the problem. Fourth, the structuredness attribute had a positive effect on perceptions of complexity. Many researchers have argued that the structuredness attribute affects the complexity attribute negatively.

However, this result did not support their assertions. It might be the case that structuredness overlaps with complexity so that the two attributes may not be clearly distinguished to the solvers. Fifth, the information richness attribute affected the perceptions of situatedness negatively. This result showed that too much information might hinder problem solvers in remembering a specific situation required for problem solving, as well as cause problem solvers to link what they have in their mind with the useful information nested in the situation. Sixth, the structuredness attribute had a positive effect on perceptions of situatedness. This result can be interpreted that a high level of structuredness enables problem solvers to identify situation with which they are familiar.

Finally, the information richness attribute had a negative effect on perceptions of complexity. This result showed that the more rich the information presented in problems, the less the perceived complexity of the problems. This study of problem characteristics enables instructional designers to develop new problems that engage learners in the real world situation. In addition, this study can support instructional designers to select a problem that has already been developed effectively

CHAPTER 1

INTRODUCTION

Context of the problem

Problem solving has been regarded as one of the most important activities in human life (Anderson, 1995; Jonassen, 2000; Meacham & Emont, 1989; Sternberg, 1994b). Some problems are fairly simple and routine so that people have little trouble in understanding the nature of problem and making a decision to solve it effectively and efficiently (Jonassen, 2003b; Simon, 1978; Smith, 1991). For example, it seems easy to search for a name on the phone directory. On the other hand, some problems such as fire fighting are extremely complex and difficult so that people may have to take unexpected risks in completing the task (Brabeck & Wood, 1990; Dillon, 2000; Greeno, 1980; Simon, 1978; Sinnott, 1989; Voss & Post, 1988). As another example, people interpret their clinical signs and symptoms in terms of their feelings about themselves, rather than measures such as body temperature. In this case, it is very hard to identify even what the problem is or how to fix it.

Over the past years, many researchers have focused their attention on understanding problem-solving performance. They have focused primarily on the theory and research that might help them identify predictors of problem-solving performance because these factors influence the degree of problem solving success (Jonassen, 2003b). In addition, instructional designers expect to be able to design effective instruction based on factors that affect such performance (Hayes, 1989; Reed, 1982; Silver & Marshall, 1990). Furthermore, identified factors allow researchers to improve theoretical problem solving models that have been investigated (Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003; Jonassen, 1997; Luszcz, 1989; Polson & Jeffries, 1983; Sinnott, 1989).

Owens Jr (1989) argued that effective classroom instructional programs could be designed by understanding what variables relate to problem-solving performance and how they interrelate. Therefore, high interest has developed, and various efforts have been increasingly made to investigate the factors that influence problem-solving performance. Many studies have been conducted to investigate influential factors on problem-solving performance and relevant approaches that support successful problem solving (Allaire & Marsiske, 2002; Jacobs et al., 2003; Jonassen, 2000; Rohlfing, Rehm, & Goecke, 2003; Smith, 1991; Taylor & Dionne, 2000). One approach for examining factors has been to present a theoretical framework of factors that may be related to problem-solving performance. The desire is to account for all factors by framework building based partly on empirical research, experiences, and suppositions. In other words, the primary aim of the research is to address as many potential factors as feasible though the relationships that exist among those factors that have not been clarified specifically.

Smith (1991) suggested influential factors that he categorized as external factors and internal factors. The main difference between the two categories depends on whether the factors are related to the personal characteristics of the problem solver or are related to characteristics of the problem. In other words, if problem-solving performance is directly affected by a factor that the problem solvers acquire through their experiences or possess in their minds, the factor is exhibited and examined as an internal factor (Frensch & Funke, 1995a; Jonassen, 2000, 2003b).

Internal factors relate to cognitive and affective variables that the problem solver possesses in order to represent and solve the problem. Internal factors that are essential to problem-solving performance have been regarded as parallel to individual differences in the sense that the variables are internally inherited, controlled, and applied by the problem solver (Jonassen, 2000, 2003b; Smith, 1991). A broad range of literature demonstrated three dimensions of internal factors as well as the importance of these factors in understanding the problem and generating possible solutions (Hayes, 1989; Kahney, 1993; Zhang, 1997).

Internal factors include cognitive predictors and affective predictors. Cognitive predictors are those that are affected by a solver's prior knowledge about specific domains, past experiences, cognitive development level, metacognition, knowledge structure of the domain, patterns of thinking, and epistemological beliefs (Bradford, Sherwood, Vye, & Reiser, 1986; Greeno, 1980; Habertlandt, 1997; Hayes, 1989; Hegarty, 1991; Jonassen, 2000; Rittle-Johnson & Alibali, 1999; Schommer, 1990, 1993; Silver & Marshall, 1990; Smith, 1991; Zhang, 1997).

Affective predictors are determinants that enable the problem solver to persist at problem solving with confidence, motivation, perseverance, interest, satisfaction, and emotion (Duch, 2001; Jonassen, 2000, 2003b; Meacham & Emont, 1989; Smith, 1991). Arlin (1989) argued that if a problem is perceived as interesting to problem solvers, it would motivate the problem solver to continually re-evaluate and react during problem solving, and that much effort will be made in an attempt to pursue desirable solutions. Greeno (1991, cited from Jonassen, 2000) found that most students did not make any effort to solve a mathematical problem if they were not able to solve the problem in a few minutes. In addition to cognitive and affective variables, Jonassen (2000), moreover, addressed general problem solving skills and strategies that individual solvers prefer to apply across knowledge domains as general factors affecting problem-solving performance.

External factors have been generally considered as variables that are directly related to the problems themselves. Jonassen (2000) described external factors as those that refer to the problem together with a situation in which the problem occurred. External factors include the problem context, structure, and formation as follows:

(1) The problem context that determines a solver's familiarity with the problem itself and the domain from which the problem is drawn (Jonassen, 1997; Meacham & Emont, 1989; Smith, 1991; Taylor & Dionne, 2000).

(2) The problem structure that constrains how well-structured, complex, and situated problems are.

(3) How the problem is represented verbally or visually (Hayes, 1989; Houdeshell, 2001; Jonassen, 1997; Lee & Heyworth, 2003; Smith, 1991; Voss, 1988; Voss & Post, 1988). That is, problems vary with the way they are represented.

(4) Social factors that encompass surrounding the social environment of the problem solver (Allaire & Marsiske, 2002; Jonassen, 2000; Lindblom & Ziemke, 2002; Peffat & Gero, 1999; Smith, 1991).

(5) The typology of problem, which refers to different kinds of problems, requiring various problem solving outcomes. (Arlin, 1989; Brabeck & Wood, 1990; Chi, 1985; Jonassen, 2000, 2002).

Another approach for investigating particular factors that affect problem-solving performance has shifted its focus from constructing a theoretical framework that explores and verifies empirically how each factor listed above impacts problem-solving performance to a focus on raw analyses of the factors, devoid of their associated theoretical propositions (Allaire & Marsiske, 2002; Lee & Heyworth, 2003; Mayer & Wittrock, 1996; Meacham & Emont, 1989; Ormerod, MacGregor, & Chronicle, 2002; Roth & McGinn, 1997; Voss & Post, 1988). A wide range of experimental studies has been conducted to capture the degrees to which factors would seem to promote successful problem solving or would seem to become obstacles to the search for solutions.

The main efforts have sought to examine the effects of such factors as the problem solver's prior knowledge (Bauer, 1991; Bernardo & Okagaki, 1994; Low & Over, 1992), metacognition (Berardi-Coletta, Buyer, Dominowski, & Rellinger, 1995; Desoete, Roeyers, & De Clercq, 2003; Kroll, 1988; Swanson, 1990; Wambach-shmidt, 1987), and motivation (Vermeer, Boekaerts, & Seegers, 2000; Zarbatany, 1985). Most previous studies used problem-solving performance, problem solving transfer, and problem representation as dependent measures, whereas they considered factors generally derived from the problem solver's personal characteristics as independent measures (Coleman, 1998; Mayer & Wittrock, 1996; Okebukola, 1990; Swanson, 1990).

With regard to the impact of a problem solver's prior knowledge on problem solving, Low & Over (1992) reported that 195 students in grades 9 and 10, who were asked to classify area-of-rectangle problems into the problems having insufficient, sufficient, or irrelevant information, demonstrated low performance when the students lacked relevant prior knowledge. Bauer (1991) conducted a think aloud protocol study concerned with understanding and identifying how people solve physical and chemical problems on the basis of conceptual knowledge of that domain. The protocols indicated the kinds of knowledge solvers were using and the way students drew upon conceptual knowledge. The findings from empirical studies indicated that the success in problem solving is conditional upon the knowledge of specific domain or context, and that problem solvers who lack specific knowledge are not expected to solve the problem.

Many studies have found that the knowledge structure adopted for representing a problem and generating solutions played a significant role in problem-solving performance (Jonassen, 1997; Kahney, 1993; Schraw, Dunkle, & Bendixen, 1995; Silver & Marshall, 1990; Smith, 1991; Zhang, 1997). Some suggest that the differences in successful problem solving among problem solvers might be attributed more to the meaningful representation of knowledge than to the amount of their prior knowledge (Silver & Marshall, 1990). Meaningful representation has successfully enabled learners to interpret the problem (Zhang, 1997), remember important information while solving the problems, and become aware of new relations among the concepts embedded in the problem (Hayes, 1989). In addition, this method encourages learners to elaborate their knowledge and reflect on their representation process while solving problems. Moreover, the knowledge structure can help learners to discover which notion is the primary one, retrieve the knowledge structure represented in their minds, and identify what pieces of information embedded in the problem are interrelated (Ferry, Hedberg, & Harper, 1998).

Metacognition is defined as a cognitive mechanism that is invoked to monitor a problem solver's cognitive processes when the problem solver engages in problem solving. (Gick, 1986; Kitchener, 1983; Roth & McGinn, 1997; Sinnott, 1989; Taylor & Dionne, 2000). Metacognition helps a problem solver to select appropriate strategies to apply to the problem, monitor his or her own cognitive process, activate a schema of domain knowledge, regulate iterative success and failure progress when the solution is applied, and control whole steps of problem solving.

Swanson (1990) investigated a group having high levels of metacognitive knowledge and found that they outperformed the group with low levels of metacognitive knowledge on problem solving. Desoete, Roeyers, and De Clercq (2003) examined 237 grade 3 children, among which the experimental group was given a metacognitive intervention for algorithmic problem solving. The experimental group performed better the other three groups that were given mathematical programs such as direct instruction, motivational program, and spelling condition.

Motivation has also generally been considered an influential factor for problem solving. Zarbatany (1985) examined the effect of motivation on social problem solving behavior by placing 103 children in a conflict play situation and coding their behaviors. If the children tried to participate in the problem situation and interact with peers positively, that behavior was regarded as a highly motivated activity. By referring to their behaviors, Zarbatany reported that problem solvers' problem solving behaviors in the situation may be influenced by motivation.

Although previous studies addressing influential factors on problem-solving performance have contributed significantly to illustrating a large number of factors in a well-organized manner, the studies have focused primarily on examining the relationships between the problem solver's personal characteristics and problem solving (Gick, 1986; Jonassen, 2000, 2003b; Smith, 1991). A majority of previous studies tended to employ internal factors rather than external factors as independent variables (Quesada, Kintsch, & Gomez, 2002). Only a few experimental studies (e.g., Jonassen & Kwon, 2001) adopted and used such external factors as problem structure or social context to assess the impact of such an external factor on problem solving. In particular, researchers have not specifically explored the impact of the problem characteristics that may affect the problem solver's representation of the problem, the integration of domain knowledge, and the selection of solutions (Houdeshell, 2001; Jacobs et al., 2003; Jonassen, 2003b; Peffat & Gero, 1999; Voss, 1988; Voss & Post, 1988).

There were some efforts to clarify what impact problem characteristics have on problem solving. Some researchers have proposed the hypothetical attributes that the problem may possess and assumed these attributes are related to problem-solving performance directly and indirectly (Allaire & Marsiske, 2002; Dillon, 2000; Hong, 1998; Jonassen, 1997, 2003b; Lee & Heyworth, 2003; Schraw et al., 1995; Voss, 1988; Voss & Post, 1988). Jonassen (2003a), for example, indicated that the four common attributes of a problem are: 1) structuredness, which refers to how well-defined and clear the problem is in its initial state, goal state, and constraints; 2) complexity, which is the degree to which the problem's initial state, goal state, possible solutions, and constraints are interwoven and interact each other; 3) dynamicity, which means the environment where the problem occurs changes over time; and 4) domain specificity, in which the problem to be solved requires specific domain knowledge. Then, Jonassen argued that these main attributes are determinants that have an effect on the success of problem solving (Jonassen, 2000, 2003a).

Meacham and Emont (1989) indicated that problems could be classified by varying degree of complexity, difficulty, importance, and urgency. Complexity is a factor of how much information is required to solve the problem and how clearly the problem is stated. Importance seems to be the degree to which the problem is significant and meaningful to a problem solver intuitively and recognizably. Urgency reflects the degree to which problem solving is perceived as a time consuming activity and to which the problem should be solved immediately. They argued that in everyday situations, these attributes become the criteria by which a solver chooses what kind of problem should be solved immediately and judges if he or she can solve the problem in view of the problem's complexity and difficulty. Therefore, these characteristics seem to be influential variations affecting the major steps of problem solving.

Arlin (1989) pointed out that a problem has three different dimensions by which the characteristics of problem can be specified. The attributes are 1) intensity, which refers to how attractive the problem is and to what degree it can cause a problem solver to get involved in problem solving; 2) temporality, which is related to a historical continuum in that the problem a problem solver met at one time is no longer the current problem; and 3) familiarity, which is the degree to which the problem is thought to be a real everyday problem to the problem solver. He argued that these characteristics help a problem solver develop appropriate problem taxonomy and distinguish various types of problems using this taxonomy. In addition, familiarity has an effect on a problem solver's generation of possible solutions and the certainty with which a problem solver reaches the solution.

Over the past years, there has been increasing agreement that problems vary in structure and complexity (Duch, 2001; Hong, 1998; Jacobs et al., 2003; Lee & Heyworth, 2003; Meacham & Emont, 1989; Wood, 1986). However, many researchers began to recognize that most problems occur in everyday situations and thus, the problems are placed in highly context dependent situations (See the chapters of Sinnott, 1989). A number of studies have mentioned the contextuality of the problem to answer the question of how the problem relates to our daily life and reflects the chaotic conditions of our workplaces. That is, the situatedness of problems is a factor that has been neglected unintentionally and can be addressed as a main attribute a problem engages (Meacham & Emont, 1989).

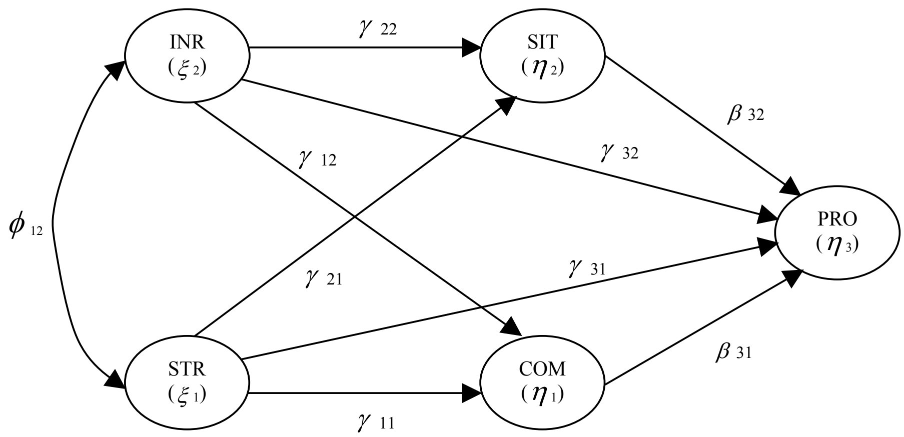
Furthermore, the kinds and quantities of information inherent in a problem, which have also been neglected or regarded as one of elements of the problem, is highlighted as a basic attribute of the problem. The problem state pertains to the knowledge state dealing with highly specific task domains. Perhaps what determines the problem's features is generated by information represented in the problem (Luszcz, 1989). These perceived attributes of the problem seem to cover almost all of the attributes listed by Jonassen (2000, 2003a), Meacham & Emont (1989), and Bassok (2003). For example, situatedness functions as domain specificity, urgency, and abstractedness. Thus, structuredness, complexity, situatedness, and information richness are considered as main attributes in this study.

However, current theoretical research and discussion regarding the characteristics of the problem have not precisely specified how these attributes may relate to problem-solving performance, nor has it been established the existence or absence of causal relationships among these variables that may influence problem-solving performance in either positive or negative ways. Furthermore, a variety of techniques from an alternative point of view have not been made to improve the understanding of what and how problem characteristics have effects on problem-solving performance (Arlin, 1989; Owens Jr, 1989; Wilson, Fernandez, & Hadaway, 1993). This study does not refute the value or significance of previous studies that have identified and summarized theoretical attributes of problems. Rather, it is attempting to extend and validate the existing studies by applying causal modeling procedures. Especially, this study adopted a series of mathematical word problems in school as the dependent measure and investigates the relationships between the perceived attributes of those problems and problem-solving performance. An overall interpretation of the result can link it to the research on the generation, diagnosis, and design of an instructional problem (Silver & Marshall, 1990; Wilson, Fernandez, & Hadaway, 1993).

Purpose of the Study

The purpose of the present study was to investigate the effect of problem characteristics in terms of perceived structuredness, complexity, situatedness, and information richness on mathematical problem-solving performance. Specifically, the present study examined the dependent measure of word problem solving from four perceived attributes of problem characteristics by formulating a causal model. This model was used to identify if the characteristics can be possible causes of problem-solving performance as well as explore the relationships among these variable attributes of problems that may account for the problem-solving performance. This model does not include any effects of individual internal characteristics such as motivation, metacognition, or the prior knowledge across the domain because, without any relevant knowledge of the subject domain, a problem solver is not expected to be able to solve the problem at all.

The effect of perceived problem characteristics on problem-solving performance is diagramed in Figure 1 below. This Structural Equation Model (SEM) reflects the true relations among the perceived problem characteristics in terms of structuredness, complexity, situatedness, and information richness. The model was constructed based on reviews of literature conveying existing studies and theoretical rationales. All subjects read a series of mathematical word problems, rated their perception of the problems in terms of problem characteristics, and solved the problems. SEM was used to analyze the effects of problem characteristics obtained from the ratings of subjects' perceptions on the problem-solving performance.



ξ_1: Structuredness ξ_2: Information richness η_1: Complexity

η_2: Situatedness η_3: Problem-solving performance

Figure 1. Hypothetical causal model

Limitations of the Study

There are some limitations of the present study. Most of all, many factors that are involved in individual internal characteristics or external environments are related to problem-solving performance. However, this study includes just four problem characteristics, structuredness, complexity, situatedness, and information richness. Therefore, the effects of other factors may not be eliminated completely, and further study is called for that examines other internal and external factors than prior knowledge in relation to problem solving.

Next, the domain in which the problem is solved can affect problem-solving performance by the selection of participants, the types of problems presented, the design of the problem solving activity, and the measurement methods and criteria. For example, if a student does not have enough mathematical knowledge to solve an algebra problem, it may be impossible for that student to solve the problem. Therefore, when a researcher tries to follow the format of this study or select a domain for further study problem solving activity, the target domain should be taken into consideration because the result of this study can be generalized only to similar domains.

Research Questions

The present study sought to investigate the following research questions:

1. How are mathematical word problems perceived by problem solvers in terms of their structuredness, complexity, situatedness, and information richness?

2. How do the perceived structuredness, complexity, situatedness, and information richness of problems relate to mathematical problem-solving performance?

3. How do the perceived structuredness, complexity, situatedness, and information richness of problems relate to each other?

Definitions of Terms

Problem's structuredness

A problem's structuredness refers to the degree to which the problem's initial state, goal state, possible solutions, and constraints are clearly specified when a problem solver encounters it.

Problem's complexity

A problem's complexity refers to the degree to which the problem's initial state, goal state, possible solutions, and constraints are interwoven and interact each other.

Problem's situatedness

A problem's situatedness is the degree to which the specific situation in which the problem takes place is related to the problem.

Problem's information richness

A problem's information richness is the degree how much domain knowledge is necessary to solve the problem.

CHAPTER 2

REVIEW OF LITERATURE

Internal factors

Internal factors are cognitive and affective variables that impact the problem solver's problem representations, reasoning, searching, and development while solving problems (Jonassen, 2000, 2003b; Frensch & Funke, 1995b; Smith, 1991). Various factors can best be understood within information processing theory and social cognitive theory. These theories explain how factors that problem solvers internalize in their mind affect their problem-solving performance psychologically, behaviorally, and cognitively. The internal factors addressed below are summarized from the variables these theories refer to.

The main factors considered are (1) prior knowledge that the problem solver has in the specific domain at hand (Frensch & Funke, 1995b; Greeno, 1980; Hayes, 1989; Jonassen, 2000; Silver & Marshall, 1990; Smith, 1991), (2) knowledge representation that is associated with prior knowledge, (3) metacognition that controls cognitive processes of the problem solver (Bradford et al., 1986; Hegarty, 1991; Zhang, 1997), (4) epistemological beliefs that require the problem solver to evaluate multiple perspectives toward the problem (Jonassen, 2000; Schommer, 1990, 1993), and (5) motivation that affects a problem solver's interest, confidence, and continuance in problem solving (Vermeer et al., 2000; Zarbatany, 1985).

Prior knowledge

When people encounter a problem, they often recognize that they have seen a similar problem before or backtrack to what they already know about the problem. While trying to discover the meaning of the problem, they call on what they have been taught or have learned from their experiences. In other words, they are attempting to represent the problem based on their existing knowledge. Prior knowledge plays a significant role in problem representation, which has been looked upon as an indispensable phase of problem solving process. Without prior knowledge, the problem solvers are not able to even start solving the problem. Chi and Glaser (1985), suggested that prior knowledge in a certain domain supports a problem solver to define what the problem requires and identify what variables prevent the problem solver from taking the next steps.

Smith (1991) argued that existing knowledge supports a problem solver to know how, when, and what techniques, strategies, and algorithms should be applied. He also said that prior knowledge allows the problem solver to trigger appropriate procedures, necessary information, and related experiences. Furthermore, Greeno (1980) stressed that prior knowledge would simplify the problem solving processes and reduce the search to transform the sequences. In summary, prior knowledge aids the problem solver to represent knowledge, elicit a limited a set of procedures, trigger the knowledge that is needed to lead toward the goal, and utilize a number of heuristic strategies and algorithms.

What kinds of knowledge does the problem solver need to solve the problem effectively? Jonassen, Beissner, and Yacci (1993) argued that problem solvers should have at least three kinds of knowledge- declarative, structural, and procedural knowledge - to solve problems successfully. Declarative knowledge, which is the awareness of some objects, events, or ideas, enables the problem solvers to define and know which information is necessary for problem solving. Structural knowledge, which refers to how information is organized, provides a conceptual basis for why we need to have knowledge to solve the problem.

Procedural knowledge, which mediates how a problem solver applies declarative knowledge relevantly, supports the problem solver to form plans, make argumentation about the problem solving processes, and relate the relevant information to problem situation. Heller and Hungate (1985) argued the necessity of distinctive knowledge for problem solving. Distinctive knowledge is knowledge for understanding and representing problems, knowledge of planning strategically, knowledge of basic concepts and principles, and repertories of familiar knowledge from the problem solver's experiences.

Hegarty (1991) suggested that problem solvers use two types of knowledge to solve problems, conceptual knowledge and procedural knowledge. Conceptual knowledge is known as the knowledge of the concepts and principles in the specific domain. The conceptual knowledge enables problem solvers to elaborate the initial statement of a given problem, define the problem, interpret the problem within their own understanding, and therefore, to represent the problem successfully. The other type of knowledge is procedural knowledge that is about how to implement the operations in the problem, manipulate the mechanism of the problem, and specialize the procedures for linking the problems with the information with which problem solvers are familiar.

Smith (1991) argued that good problem solving is enhanced by knowledge of general problem solving procedures as well as domain specific problem solving procedures. He emphasized that knowledge allows the problem solver to reason why some procedures are appropriate and effective and modify their performance when they meet new problems. From these studies, it is argued that knowledge is an essential part of problem solving and makes a contribution to successful problem solving in various ways (Bauer, 1991; Rittle-Johnson & Alibali, 1999; Smith, 1991; Voss & Post, 1988).

Knowledge Representation

With few exceptions, researchers have supported that knowledge representation, which is about how problem solvers structure their prior knowledge, plays a significant role in problem-solving performance (Jonassen, 1997, 2000; Kahney, 1993; Silver & Marshall, 1990; Zhang, 1997). Some suggest that the differences in successful problem solving among problem solvers might be attributed more to the meaningful representation of knowledge than to the amount of their prior knowledge (e.g., Polya, 1973, cited in Silver & Marshall, 1990). Like prior knowledge, knowledge representation has successfully enabled learners to interpret the problem (Zhang, 1997), remember important information while solving the problems, and become aware of new relations among the concepts embedded in the problem (Hayes, 1989).

In addition, internal knowledge representation encourages the problem solvers to elaborate their knowledge and reflect on their representation process while solving problems (Wilson et al., 1993). Moreover, internal knowledge representation can help learners to discover which concept is the primary one, retrieve the knowledge structure represented in their minds, and identify what information embedded in the problem is related to concepts in their internal representations (Ferry et al., 1998). In short, knowledge representation is important to think about the organization of the knowledge needed for problem solving and its relationship with information expressed in the problem.

A number of studies have showed the significant role of internal knowledge representation on successful problem-solving performance (Chi & Glaser, 1985). Robertson (1990) found that the extent to which the knowledge structure was organized was a strong predictor of how well problem solvers solved transfer problems in physics. He analyzed think aloud protocols and concluded that knowledge structure connecting physical formulas with important concepts was important to successful problem-solving performance.

Okebukola (1990) examined students' performance in a biology course and found that the 63 students who generated their own knowledge structure in the form of knowledge map to study genetics and ecology significantly outperformed the other 63 who learnt the material presented by the instructor at solving genetics problems. Coleman (1998) reported that a group that generated their own knowledge structure showed significantly greater problem-solving performance than the other group that was given instructor-led instruction. A series of experiments show that knowledge structures internally represented by problem solvers directly or indirectly related to successful problem-solving performance.

Metacognition

Metacognition is the cognitive control that problem solvers use to manage their thinking and learning processes (Flavell, 1978). Brown (1987) referred to metacognition as the extent to which learners engage in regulating and monitoring their own learning processes. In short, metacognition is the learner's awareness of the learner's cognition. The two components of metacognition that are generally accepted among researchers: metacognitive knowledge and metacognitive regulation. Metacognitive knowledge is the knowledge about a series of cognitive strategies related to metacognitive regulation, which includes checking, planning, monitoring, testing, revising, and evaluating the cognitive process (Baker & Brown, 1984).

Metacognition has been related to a variety of cognitive activities (Swanson, 1990). In particular, metacognition has been described as an essential part of problem-solving performance (Desoete et al., 2003). Metacogntion helps problem solvers to monitor and regulate their cognitive processes, values of alternative solutions, and comprehension of strategies (Jonassen, 1997). Kitchener (1983) maintained that metacognition assists solvers in extracting knowledge and strategies that may be invoked to solve the problem.

Some examples of the effect of metacognition on problem-solving performance contrast with verbalization of the problem solver's processes. Berardi-Coletta and colleagues (1995) conducted a study to identify the effect of verbalization on solution transfer. They found that solution transfer relied not on verbalization per se but on metacognitive process. Specifically, when students were asked about what they are doing and why, they were able to solve problems more efficiently and transfer solution knowledge to more complex problems than other students who were simply told to produce think-aloud protocols.

The think-aloud protocol (Ericsson & Simon, 1984, 1993) is specifically designed not to affect metacognition by asking participants not to talk about their thinking processes, but to vocalize words that come to mind as they solve a problem. On the other hand, some researchers have asked participants to verbally evaluate their cognitive processes while solving a problem thus eliciting metacognition.

In a study of metacogntion, Desoete, Roeyers, and Clercq (2003) conducted a study to investigate the effect of metacognition on algorithmic cognitive problem solving in an elementary school. From the result of the experiment, they concluded that children in the metacognitive group had significantly higher posttest mathematics problem solving scores than children in other groups, who received direct instruction, a motivational program, or a spelling program. They concluded that children in the metacognitive group had higher prediction scores of problem solving than children in other groups. Evidently, metacognition positively affects problem-solving performance.

Swanson (1990) assigned participants who received a rate of metacogntion above the median rate to a high metacognitive knowledge group and those who received a rate at or below the median to low metacognitive knowledge group. He investigated whether high rate of metacognitive knowledge affected the problem-solving performance of 56 children from grades 4 and 5. The finding was reported that high metacognitive children outperformed lower metacognitive children in problem solving. In summary, metacognition provides problem solvers with assistance to regulate their cognitive process for successful problem-solving performance.

Epistemological Belief

Epistemological beliefs, which are personal beliefs about the nature of knowledge and learning, have been found to relate to problem-solving performance (Jonassen, 2000; Schommer, 1993, 1994). Previous studies provide evidence of the importance of epistemological beliefs to learning in that they affect the learner's active engagement in learning, persistence in difficult tasks, and comprehension of the information. Epistemological belief also relates to ill-structured problem-solving performance (Schommer, 1994). Epistemological belief has a strong relationship with their problem-solving performance if problem solvers meet an ill-structured problem that requires them to think through more than one solution, path, and representation of the problem.

Those factors of epistemological belief are factors related to integrating information with the learner's prior knowledge to solve the problem. Epistemological belief also relates to persistence in mathematical problem-solving performance. Schoenfeld (1985) found that high school students believed any kind of mathematical problem should be solved within 12 minutes. Sometimes, many students believed that they should not spend over 5 minutes on a problem. In conclusion, epistemological belief is a new factor that has not been paid much attention in the domain of problem solving. However, it is an important factor to relate to successful problem solving in terms of integration of information, persistence, and active engagement.

Affective variables

Many researchers have agreed that the essential characteristics of problem solving center on cognitive and metacognitive ability and knowledge. However, those are necessary but insufficient requirements for successful problem solving. Jonassen (2000) argued that the more important consideration toward problem solving should be focused on affective factors such as self-confidence and motivation. The affective domain includes attitude, emotions, values, and motivation.

Martin and Reigeluth (1999) defined affective domain as "components of affective development focusing on internal changes or processes, or to categories of behavior within affective education as a process or end product." (p. 486). The affective domain is important in all aspects of learning and has some positive influence on successful problem solving as learners get involved in authentic learning environments (Jonassen, 2000). Many theories and models related to the affective domain have stressed motivation as a preliminary and fundamental component that should be considered above other components (Spitzer, 1996).

The impacts of motivation on problem solving are various. Motivation enables problem solvers to participate in a problem situation actively. Problem solvers are not meant to sit passively in classroom. When they are highly motivated, they desire to make choices and solve the problem. The motivation to succeed also causes problem solvers to persist at complex situations for a long time. Fun motivates problem solvers to solve the problem in spite of failures of trials. Even though a complex problem situation may result in failure, fun allows the problem solver to try to solve the problem again more energetically.

In addition, problem solvers will respond to the situation enthusiastically to overcome barriers. They will commit to achieving the goal because motivation causes them to regard the complex problem as a personal challenge (Spitzer, 1996). Perkins and Hancock (1986, cited from Jonassen, 2000) found that some students immediately gave up solving problems when they felt that the problem was more complex than they believed they could solve. However, learners' motivation provided the level of mindful effort and perseverance that can be applied to successful problem-solving performance.

External factors

Problem Context

The problem context refers to the degree to which a problem solver is familiar with the problem itself and the domain from which the problem is drawn (Jonassen, 1997; Meacham & Emont, 1989; Smith, 1991; Taylor & Dionne, 2000). The degree of familiarity of problem solver with problem type depends upon their prior knowledge and experiences. Arlin (1989) addressed the discrepancy and recognition of similarity or contradiction between what learners have experienced and what they encounter in the problem. These similarities and contradictions imply that the problem can be perceived as a complex situation in which the problem is to be solved in light of what they have seen or thought in their daily lives.

It suggests that problem solving is closely tied with the problem solver's familiarity with the problem, and the usefulness of its familiarity should be taken into account along with successful problem-solving performance. Familiarity as an external factor is helpful to represent the problem, activate previous knowledge, and recognize the problem more precisely when problem solvers engage in a problem situation. Thus, familiarity of the problem is equated with everyday problems that occur in everyday life outside the classroom.

Lee and Heyworth (2003) investigated the effect of familiarity of the problem on problem solving with the hypothesis that it was easier for students to solve familiar problems than unfamiliar problems. They taught university students the topic of logarithms with three steps that included the simplification of numerical expressions, the simplification of expressions involving variables, and the solving of logarithmic problems. Whenever problem solvers went through each stage, they repeatedly applied the knowledge learned from the earlier stage to later stage. Familiarity was tested by the degree of familiarity problem solvers assigned to the problems in each stage. The result was that, for the most successful problem solvers, the problem encountered in earlier stages was more familiar to them. The correlation between familiarity and problem solving was positive ($r = .74$).

Social factors

Social factors include the surrounding social context, the physical environment, and peer interaction (Allaire & Marsiske, 2002; Jonassen, 2000; Smith, 1991). Taylor and Dionne (2000) referred to social factors as one of the characteristics of the problem solving process. Many researchers have also stressed the significant role of socio-cultural factors on problem-solving performance (e.g., Allaire & Marsiske, 2002). Though social factors are not sufficient for explaining successful problem solving, it is necessary to note that problem solving is shaped by the social context, cultural background, physical space, and dynamic relationships among participants in problem solving. Pretz, Naples, and Sternberg (2003) proposed that social contexts involving peers, culture, and language have key roles in recognizing, defining, and representing a problem.

The recognition of social context plays a role in the discovery of the problem situation. The definition of the problem can be changed by the agreement of peer cooperation. Even though I define a problem in a particular way, problem solvers may not confirm and have different opinions. The problem definition is affected by the environment in which the problem solver participates or the group members with whom the problem solver get involved. The problem representation is also context-dependent activity. The context in which problem solvers attempt to solve the problem requires them to understand the problem from multiple perspectives depending on their situations.

Typology of the problems

The typology of a problem refers to different problem types, requiring various problem solving outcomes, solutions, and contexts (Arlin, 1989; Brabeck & Wood, 1990; Chi, 1985; Jonassen, 2000, 2002). Problems can vary with problem types. Many of researchers such as

Dillon (2000), Jonassen (2000), Kitchener (1983), and Sternberg (1994a) suggested the dichotomization of problem type as well-structured problem and ill-structured problem (The detailed definition and characteristics of structuredness in problem are described in the next section of the chapter). The table listed below presents an overview of typology of the problems, which will be useful for understanding different types of problems.

Of those types, interestingly, Brabeck and Wood (1990) divided problem types into 3 categories, which are "with certainty", "under risk", and "inference". This typology seems to be solely based not on the attributes of the problem, but rather on statistical concepts about probability. Although Jonassen (2001, 2002) addressed 11 types of problems that vary with regard to outcome, solution, context, structuredness, and abstractedness, this typology needs to be validated and explicated further. In addition, Greeno (1978) suggested a typology of problem types on the basis of cognitive processes required for finding a solution. Unlike other typologies, Greeno associated his typology with cognitive processes (Singh & Zwirner, 1996). The typology of problems addressed by various researchers is shown in Table 1.

Table 1. Typologies of problems

Researcher(s)	Types	Description
(Jonassen, 2001, 2002, 2003a)	Logical problem	Abstract test of logic
	Algorithmic problem	Mathematical problem
	Story problem	Situated algorithms in some kind of context
	Rule-Using problem	Rule-oriented process problem
	Decision-making problem	Decision about alternatives problem
	Trouble-shooting problem	Fault state diagnosis problem
	Diagnosis-solution problem	Fault identification and treatment problem
	Tactical-strategic performance	Real time and complex performance problem
	Situated case/policy problem	Decision, action, and argumentation problem
	Design problem	Articulation, options, design, and argumentation problem
	Dilemma	Complex non-predictive problem
(Chi & Glaser, 1985)	Classroom problem	Problems solved in the classroom
	Real world problem	Everyday life problem outside the classroom
(Arlin, 1989)	Presented problem	Little innovation and creativity for finding a solution
	Discovered problem	Greater intervention and creativity for finding a solution
	Ill-structured problem	Problem without certainty and completeness
	Well-structured problem	Specified problem with certainty and completeness
	Ill-defined problem	Clear definition of problem components
	Well-defined problem	Unclear definition of problem components
(Jonassen, 1997, 2000)	Well-structured problem	Application of a limited number of regular rules and principles
	Ill-structured problem	Everyday problem and integration of several content domains
(Kitchener, 1983)	Well-structured problem	Problem solved by the correct application of an algorithm
	Ill-structured problem	Real world problem
(Brabeck & Wood, 1990)	“with certainty” problem	Problem solved with certainty
	“under risk” problem	Problem solved probabilistically
	“inference” problem	Problem solved with a degree of confidence
(Schraw, Dunkle, Bendixen, 1995)	Ill-defined problem	Problem with various processes and multiple solutions
	Well-defined problem	Problem with one correct answer and procedure
(Allaire & Marsiske, 2002)	Ill-defined problem	Everyday life problem
	Well-defined problem	Traditional problem referring to problem space theory
(Dillon, 2000)	Well-structured problem	Problem with high degree of structure
	Ill-structured problem	Problem with some limited degree of structure
(Greeno, 1978)	Inducing structure problem	Problem for identifying the pattern of relations
	Transformation problem	Problems for finding a sequence of operations that transforms the problem
	Arrangement problem	Problem for arranging problem components
(Pretz, Naples, & Sternberg, 2003)	Ill-defined problem	Problem with radical change of components
	Well-defined problem	Problem solved using a set of recursive operations or algorithms
(Wenke & Frensch, 2003)	Complex problem	Ill-specified problem with dynamic change of the problem situations
	Simple problem	Well-specified problem with clear definition
(Lubart & Mouchiroud, 2003)	Creative problem	Problem solved by unpredictable ways
	Noncreative problem	Problem solved by pre-established algorithmic procedures
(Scriven, 1980)	Within-paradigm problem	Problem commonly encountered in the classroom
	New-paradigm problem	Problem requiring a new approach, paradigm or theory

Characteristics of a Problem

Over the past four decades, several researchers have examined hypothetical attributes of the problem that may influence problem-solving performance (Allaire & Marsiske, 2002; Dillon, 2000; Jonassen, 1997, 2003b; Lee & Heyworth, 2003; Pretz et al., 2003; Robertson, 1990; Schraw et al., 1995; Voss, 1988; Voss & Post, 1988). Their research has focused largely on investigating what determines the characteristics of a problem with the basic assumption that influential attributes or variations are independent of each other. They made clear distinctions among attributes in terms of the structure, substance, process, time, preferences, and importance in which problems vary (Jonassen, 2002; Meacham & Emont, 1989). Arlin (1989) stated that a problem consists of three different dimensions applied to different kinds of problems.

The attributes that are closely related to problem solving are intensity, temporality, and familiarity. Intensity refers to the attractiveness the problem has and if it appeals to problem solvers to participate in problem solving process with interest. Next, temporality is the historical remembrance of a problem that the problem solver has seen. This attribute concerns whether the problem solver has encountered similar or almost the same problem before, and whether the time the problem solver met the problem is long ago.

Finally, familiarity is the degree to which the problem has been encountered by the problem solver in real daily life, and the extent to which the problem solver treats the problem in same way as the problem the problem solver previously encountered. Arlin (1989) argued that these characteristics help a problem solver to develop appropriate problem taxonomy and to distinguish various types of problems from this taxonomy. In addition, these factors affect choices of possible solutions and the certainty with which a problem solver reaches a solution.

Jonassen (2003a) stated that most common attributes of a problem are four-fold. A problem has a degree of structuredness, the attribute that refers to how well-defined and clear the problem is in its initial state, a goal state, and constraints. The number of attributes has much to do with the number of concepts, rules, and principles needed for problem representation, the factors involved with searching for solutions, and criteria for evaluating the solution. Second, complexity is how complex the components of the problem are interwoven and how difficult it is to isolate each component separately.

Third, dynamicity is related to an environment where the problem occurs if conditions of problems seem to be stable or dynamic. If the condition of the problem is dynamic, the problem solver adapts to the environment impacting the problem and takes a new approach to solve the problem because the old approach is not available now. Fourth, domain specificity concerns whether the problem to be solved requires specific domain knowledge. Problem solving activity is sometimes so situational, technical, and specific that it is difficult for the problem solver with limited knowledge about the domain to plow through. Many existing references have stressed the importance of specific domain knowledge (See, Sternberg & Frensch, 1991). Then, Jonassen argued that the main attributes are determinants that have effects on the success of problem solving (Jonassen, 2000, 2002, 2003a).

Meacham and Emont (1989) argued that problems vary with the degree of complexity, difficulty, importance, and urgency. Complexity refers to how much information is addressed in the problem and how clearly the problem's initial and goal states are identified. Difficulty is distinguished from complexity in that difficulty concerns characteristics of the problem solver as they interact with characteristics of the problem whereas complexity concerns characteristics of the problem. Importance is about the degree to which the problem is significant and meaningful to a problem solver intuitively and recognizably. Urgency refers to the degree to which solving the problem is time a consuming activity and should be solved as soon as possible in order to save time. Meacham and Emont argued that in everyday situations, these attributes become the criteria that affect problem solvers' choices regarding what kind of important problem should be solved immediately and how they judge if they can solve the problem without consideration of complexity and difficulty. Therefore, these characteristics seem to be influential variations affecting the major steps of problem solving.

Bassok (2003) described the attributes of the problem as similarity, abstraction, and continuity. Similarity means the knowledge stored in problem solvers' mind, and the target problem that the problem solvers encounter, are interrelated. Abstraction refers to the inclusion of content, context, and phrasing of a problem that can keep problem solvers from overgeneralizations to problems that differ in any one of these aspects when problem solvers encounter novel problems. Continuity of the problem is the degree to which problems are changing constantly and can be solved in the same way as they were solved previously. The author pointed out that these attributes are useful to retrieve relevant prior problems, solutions, and transfer knowledge from prior learning to a problem in a different context.

There has been increasing agreement that problems vary in structure and complexity (Duch, 2001; Hong, 1998; Jacobs et al., 2003; Lee & Heyworth, 2003; Meacham & Emont, 1989; Wood, 1986). However, many researchers began to realize that most problems occur in everyday situations and thus, the problems are placed in highly context dependent situations (See the chapters of Sinnott, 1989). A number of studies have paid attention to the contextuality of the problem to answer the question of how the problem relates to our daily life and reflects the chaotic conditions of our workplaces. That is, the situatedness of problems is a factor that has been neglected unintentionally and can be addressed as a main attribute of the problem (Meacham & Emont, 1989).

Furthermore, the kinds and quantities of information inherent in a problem, which have also been neglected or regarded as one of elements of the problem, is highlighted as a basic attribute of the problem. The problem state pertains to the knowledge state dealing with highly specific task domains. Perhaps what determines the problem's features is generated by information represented in the problem (Luszcz, 1989). These attributes of the problem seem to cover almost all of the attributes listed by Jonassen (2000, 2003a), Meacham & Emont (1989), and Bassok (2003). Situatedness covers domain specificity, urgency, and abstractedness. From the review of characteristics mentioned above, structuredness, complexity, situatedness, and information richness are considered as main attributes in this study.

Structuredness

Description. Structuredness has been referred to as intrinsic value of the structure that a problem provides. That means, how clear and solid the structure of the problem is decides the nature of the problem itself. Each problem has its own structure and presents it through some elements of the problem such as the goal to be achieved. Various judgments for recognizing the problem's structuredness can be made by identifying the initial state, the goal state, constraints of the problem, operators and applications of concepts and rules required for problem solving (Allaire & Marsiske, 2002; Chi, 1985; Greeno, 1978; Jonassen, 2000, 2003b; Luszcz, 1989; Sinnott, 1989; Wood, 1983).

One of the criteria to identify the structuredness is the initial state of the problem, which refers to a stimulus situation for which a problem solver does not have a ready response. Goal state refers to the desired outcome the problem solver wants to achieve at the end. An operator is any means or solution to solve the problem (Allaire & Marsiske, 2002). Constraints are the restrictions that hinder the problem solver to advance the progress of the problem solving. Application entails the number of concepts, rules, and principles to be applied. These components are nested in the problem and, by searching them, problem solvers recognize the structuredness of the problem.

The impact of structuredness on problem-solving performance is obvious (Allaire & Marsiske, 2002; Brabeck & Wood, 1990; Dabbagh, 2002; Dillon, 2000; Houdeshell, 2001; Jonassen, 2000; Sinnott, 1989; Voss & Post, 1988). Voss (1988) insisted that the structuredness engages in changing a problem solver's problem solving process from a routine procedure with which the problem solver is familiar to one of unexpected procedures that he or she judges and decides. Sinnott (1989) and Voss and Post (1988) argued that structuredness influences the problem solver to search and select the information, generating and selecting solutions, evaluating solutions, and monitoring the problem solver's problem solving processes.

Moreover, structuredness supports the problem representation process that is an essential step for successful problem solving (Brabeck & Wood, 1990; Duch, 2001; Jonassen, 1997; Polson & Jeffries, 1983; Rittle-Johnson & Alibali, 1999). If the structure of the problem is not organized well, it is difficult to extract the final goal from the initial statement of the problem. In other words, structuredness can facilitate the understanding of the problem or prevent problem solvers from decomposing the problem statement.

Generally, researchers have categorized problems according to whether all components of the problem exist or not. Problems with clear initial states, solutions, and constraints are termed well-structured problems. Problems with vague statements of the problem are termed ill-structured problems. Hong (1998) made a distinction between well-structured problems and ill-structured problems in terms of components of problem statements, solutions, problem solving processes, cognition, justification skills, etc.

However, this categorization is to represent the clarity in problem solving rather than make a boundary between types of problems (Sternberg, 1994a). Thus, this distinction between two types of problems should be viewed as continuum rather than discrete dichotomy (Jonassen, 1997; Voss, 1987). For the purposes of the current study, the clarification of the distinction between well-structured problem and ill-structured problem is described in following statements.

Well-structured problem. Just as the term is described, a well-structured problem is a problem that has internal structure in well-organized manner. Jonassen (2000) defined the well-structured problem as a problem commonly encountered in schools that requires the application of information and a number of algorithmic rules to constrain the problem situation. His definition has stressed the place where the problem happens and the application of the information. Greeno (1978) termed a well-structured problem as a problem that has a well-defined initial state, a known goal state, finite number of constraints, and constrained set of logical states.

Whereas Kitchener (1983) and Sternberg (1994a) tried to define a well-structured problem in light of solutions, Kitchener (1983) stated that a well-structured problem is a problem that has all the elements necessary for a solution and has an effective procedure to be solved. Sternberg (1994a) defined the well-structured problem as a problem with a well-defined path to its solution. The definition typically cited by researchers is defined by Newell and Simon (1972). They made mention of whether the goal of the problem is well defined, the given information is well addressed in the problem, and whether the constraints of the problem are provided or not.

Jonassen (1997) described the nature of a well-structured problem more specifically. A well-structured problem has all elements of the problem, an apparent definition with a probable solution, a limited number of concepts and rules required for solving the problem, a correct and right answer, a solution preferred by the problem solver, and a domain dependent situation. Meacham & Emont (1989) also made reference to well-structured problems in a similar manner with Jonassen (1997). According to the definition posed their study, a well-structured problem is individualistic, well-defined, elicits one task at a time, has a limited time frame, has one correct answer, and requires no value issues.

Schraw, Dunkle, & Bendixen (1995) suggested a criterion by which to distinguish well-structured problems from ill-structured problems. They mentioned that a well-structured problem must have only one correct solution with certainty and there should be best procedures to reach the solution effectively and efficiently. Allaire and Marsiske (2002) also addressed the nature of the well-structured problem by comparing well-structured problems with ill-structured problems. Well-structured problems can be solved efficiently with a single correct solution and be clearly stated in terms of three components, which are initial state, operators, and goal state. In summary, a well-structured problem has a clear statement of problem's components, one single correct solution, algorithmic paths to reach the goal, and applications of a finite number of concepts, rules, and principles to constrain the situation.

To understand what the well-structured problem is, three examples are taken on as specific cases of a well-structured problem. First, these problems are analogical problems that deal with the problem solvers' mathematical performance to apply mathematical formulas and calculate solutions without errors. Second, these problems are analogical problems that ask problem solvers to examine the relationship between two items and transpose that relationship onto two other items. Third, these problems are mechanical problems that require problem solvers to concern themselves about physical formulas and principles in relation to mechanics. These three problems have clear initial states, operators, goals, and constraints. Based on the components of these problems, the problem solvers are likely to use different concepts, rules, and principles, and finally solve the problems.

(1) "Mr. Russo takes 3 minutes less than Mr. Lloyd to pack a case when each works alone. One day, after Mr. Russo spent 6 minutes in packing a case, the boss called him away, and Mr. Lloyd finished packing in 4 more minutes. How many minutes would it take Mr. Russo alone to pack a case?"
(An algebra problem cited from Hayes, 1989, p. 13)

(2) "Nefarious is to Dromedary as Eggs are to:
A: Chapel B: Yellow C: Bees D: Friend"
(An analogy problem cited from Pretz, Naples, and Sternberg, 2003, p. 10)

(3) "A little boy needs to lift a bale of hay from the floor of his father's barn to the loft. The bale weights 60 lbs. but the boy can only lift with a force of 20 lbs. He has some pulleys and ropes at his disposal. How can he use these pulleys and ropes to lift the weight?"
(A mechanical problem cited from Hegarty, 1991, p. 257)

Ill-structured problem. In opposition to a well-structured problem, an ill-structured problem is a problem that has highly intricate structure and can't be solved in predictive and obvious ways. Many researchers have tried to define the ill-structured problem in order to avoid misinterpreting the ill-structured problem in contrast to the well-structured problem, as well as to suggest new approaches to solve kinds of the problem by clarifying the elements of the problem (Allaire & Marsiske, 2002; Dillon, 2000; Duch, 2001; Gick, 1986; Greeno, 1980; Kitchener, 1983; Meacham & Emont, 1989; Schraw et al., 1995; Sinnott, 1989; Voss, 1988; Voss & Post, 1988).

Chi & Glaser (1985), defined the ill-structured problem as one that lacks one or all of the three components, which are the initial state, permissible operators, and the goal state. In other words, for ill-structured problems, it is difficult to specify the initial state, formulate possible actions taken to modify the initial state, and reach the goal. Kitchener (1983) proposed that an ill-structured problem is a problem that has no single or unique solution and employs a particular decision-making process while solving the problem.

Voss (1988) argued that an ill-structured problem has a vague goal, minimal givens, and a lot of constraints to be overcome. Sinnott (1989) defined an ill-structured problem as one for which there is no single correct solution and little certainty about solutions. Like Sinnott (1989), Arlin (1989) regarded the certainty of the solution as a major property of an ill-structured problem. In addition to the certainty, she added the completeness with which a problem can be clarified is another major characteristic of an ill-structured problem.

How can we distinguish the ill-structured problem from the well-structured problem? Some researchers have suggested guidelines for making a distinction between them. Jonassen (1997) suggested that the main differentiations between two types of problems depend on whether the ill-structured problem lacks one or more of the problem components, is difficult to define, possesses multiple solutions and paths to reach the goal, requires different information in a case-by-case analysis, and requires judgment about the solution. Dillon (2000) pointed out that the ill-structured problem is short of one of following, knowledge of the goal or objective, familiarity of the situation by the decision maker, definition of the goal state, the number of potential solutions, and rigorous criteria by which to judge potential problem solutions.

Allaire and Marsiske (2002) contended that if the initial state, solutions, or the end state were not evidently specified, the problem would be looked upon as an ill-structured problem. Sometimes, an ill-structured problem can be best described by extended time frame, possible solutions, inherent value issues, and necessary knowledge (Meacham & Emont, 1989). In addition, Schraw, Dunkle, & Bendixen (1995) stated that an ill-structured problem has multiple solutions, multiple representations, and multiple paths to arrive at the goal. In summary, the criteria suggested by Sinnott (1989) to distinguish the two types of problems, well-structured and ill-structured, expands boundaries and seems to cover each of the criteria mentioned above. Her criteria are initial state, goal state, operators, rules, modification of the process, emotional states, and evaluation of the process.

The following examples are illustrated to show a series of ill-structured problem and how they are recognized. First problem is an insightful problem that leads to different solution paths. The second problem is an international affairs problem that involves antagonistic relationships among other countries. The decision should be made with careful consideration because the final decision may lead to a more serious problem. The third problem is an economics problem that requires diagnostic treatment of political and economic stability. Unlike well-structured problems, these problems are ill-defined and have unclear goals and multiple solutions and paths to make a decision. Decisions are also made and evaluated with consideration of the problem solvers' values.

> "A man who lived in a small town in the U.S. married 20 different women of the same town. All are still living and he has never divorced one of them. Yet he has broken no law. Can you explain?"
> (An insightful problem cited from Pretz, Naples, & Sternberg, 2003, p. 18)

> "One of the first acts of the new government was to schedule a series of high level meetings between representatives of the governments of East and West Germany. The purpose of the meeting is to "coordinate clean-up operations and facilitate communications in times of crisis."… Recognizing the concern of NATO allies, most members of parliament have focused their attention on the presence of Soviet forces in the east….What options do you think the Soviet Union has in responding to the events described above? Indicate which option they are most likely to pursue, and provide your rationale for selecting this option."
> (An international affairs problem cited from Voss, Wolfe, Lawrence, and Engle, 1991, p. 155)

> "Suppose you are advising a small country (such as Bermuda) on whether to print its own money or to use the money of its larger neighbor (such as United States). What are the

costs and benefits of national money? Does the relative political stability of the two countries have any role in this decision? Explain."

(An economics problem cited from Cho and Jonassen, 2002, p. 9)

Complexity

Description. Problems may vary with respect to their complexity, which is the degree to which the elements of a problem are interwoven and interrelated among each other. Sometimes, the two attributes complexity and structuredness have been used by some researchers interchangeably and overlapping invariably (Jonassen, 2000). Obvious differences between the two attributes include how many, how clearly, and how multidimensionally components of the problem are represented in predictable ways. If the number of components and clearness of the problem are focuses of the problem statement when the problem solver read the problem, the structuredness of the problem is highlighted and regarded as main influential attributes of the problem.

However, when the relationships among components of the problem are typically paid attention by the problem solver, complexity is highlighted. Problem complexity is, in part, correspondent to problem difficulty. The more complex a problem is, the more difficult it will be for problem solvers to make out the elements of the problem. On the contrary, the more difficult a problem is, the more complex it will be for problem solvers to identify the associations among the elements of the problem.

Wood (1986) defined the meaning of complexity using three dimensions. He suggested that the complexity in the problem is composed of component complexity, coordinative complexity, and dynamic complexity. Component complexity is a direct function of distinct acts needed for performing a certain task and the distinct information needed to perform these acts. Coordinative complexity is the nature of relationships among certain tasks and information needed to perform the task. Dynamic complexity is the degree to which relationships between the task and the information is transformed by changes in the external situation. His point of view for problem complexity makes implications that complexity consists of the functions of each element, their reciprocal interaction, and the effect of external factors on the problem. Jonassen (2003a) elaborated the characteristics of problem complexity as determined by how many issues are involved in a problem, the degree of their association, the types of functions of each element, and the stability of each element. His view of problem complexity is thus close to that of Wood (1986).

Complexity is presumed to affect successful problem solving directly. The more complex a problem is, the more difficult it is for a problem solver to find a solution. For example, Jacobs, Dolmans, Wolfhagen, & Scherpbier (2003) conducted a study examining students' preference toward complex problems. The result showed that the complexity made it difficult for students to choose the best method to solve the problem, and the students felt that complexity led to failure of the problem solving. Voss, Wolfe, Lawrence, & Engle (1991) compared the information processing of problems solvers in international relations. They found that the problem solvers represent complex problems in different ways that lead to different kinds of solutions. Sokol & McCloskey (1991) conducted a study in which they provided an arithmetic calculation problem to students. The problem that looked like a simple calculation problem was actually a complex problem. The result revealed that solving a complex problem requires interplay among cognitive processes.

Generally, researchers have divided problems into two types according to the degree of their complexity (Albers, 2002; Duch, 2001; Jonassen, 1997, 2000, 2003b; Sokol & McCloskey, 1991; Wenke & Frensch, 2003; Wood, 1986). Like the distinction made between well-structured problems and ill-structured problems, problems can be classified as simple problems and complex problems, depending on the levels of complexity (Wenke & Frensch, 2003). The term "simple" implies that the relationship between elements of the problem is easy to distinguish and the term "complex" means the relationships among the elements are so complicated that the problem solver may have difficulties in solving the problem.

However, simple problems and complex problems do not constitute a dichotomy, but instead represent points on a continuum. A problem may have simple relationships among elements at some points and complex relationships at other points. In addition, whether the problem is simple or complex depends on the function of what and how the elements interact and are interrelated with each other.

Simple problem. A simple problem is a problem in which the elements of the problem are simply and clearly interrelated. As previously mentioned in structuredness, the problem has an initial state, a goal state, constraints, and a set of operators. In general, the simple problem tends to have apparent elements and simple relations among them. In other words, the simple problem is composed of a few components that may interact in predictable and simplified manners (Jonassen, 2003b). In addition, a simple problem does not require as many cognitive operations as a complex problem does (Kluwe, 1995). There have been persistent beliefs among problem solvers that it is relatively easier to solve the simple problem than the complex problem, and that textbook problems are good examples of simple problems.

Contrary to these beliefs, there is some evidence that if problem solvers have little knowledge about the specific domain, they can't solve the problem irrespective of the levels of complexity, and those textbook problems include simple problems as well as complex problems (Greeno, 1980; Huber, 1995; Kyriakides & Gagatsis, 2003; Peffat & Gero, 1999; Roth & McGinn, 1997; Simon, 1978). Funke (1991) argued that a simple problem should be characterized by the following criteria. If a problem has a great deal of available information, precision of goal definition, linear connectivity among variables, stability, and certainty among variables, the problem is relatively simple. Availability of information refers to the phenomenon that most of the variables lend themselves to direct observation so that problem solvers can infer the underlying state hidden in the problem. The precision of goal definition refers to how many goals are specified in the problem representation.

The degree of connectivity refers to how components are interrelated and whether their relationships are linear or nonlinear. Stability of the problem refers to whether the problem is dynamically changing over time. Certainty means the knowledge necessary for solving a problem is embedded in the problem. Berry (1991) argued that the criteria to make a decision about whether a problem is complex or not depends on the number of components nested in the problem, their interconnectivity, the intransparency, the time lag, and the number of goals (Frensch & Funke, 1995b).

Although the definition and characteristics of simple problems are addressed above, it may be better to go through the real examples of simple problems. Quesada, Kintsch, and Gomez (2002) suggested some examples of simple problems and complex problems based on the classical definitions of problem solving. The following are simple problems they suggested:

> "One vegetable oil contains 6% saturated fats and a second contains 26% saturated fats. In making a salad dressing how many ounces of the second may be added to 10 oz. of the first if the percent of saturated fats is not to exceed 16%?"
> (From a work problem cited from Hayes, 1989, p. 13)

"Dickens, Einstein, Freud, and Kant are professors of English, Physics, Psychology, and Philosophy (though not necessarily respectively).

1. Dickens and Freud were in the audience when the psychologist delivered his first lecture.
2. Both Einstein and the philosopher were friends of the physicist.
3. The philosopher has attended lectures by both Kant and Dickens.
4. Dickens has never heard of Freud.
5. Dickens and Einstein met the English professor.

Match the professors to their fields."
(A matching problem cited from Hayes, 1989, p. 17)

Complex problem. In the book "Complex Problem Solving: The European Perspective" (p.14), all of the contributors to the book addressed their own definitions of the complex problem (solving). In the following, some definitions of the contributors are introduced to present the diversity of conceptualizations of complex problems.

> Complex problem solving represents a class of task demands the cognitive mastery of which calls for the recognition of causal relations among the variables of a system (Beckmann & Guthke, 1995).

> Deciding whether a task should be considered as being complex or not, seems to be relative rather than an absolute issue. Some tasks seem to be complex when compared with many traditional experimental problem-solving tasks. In these cases, the large number of variables and their interconnectivity, the intransparency, the time lags, and the large number of goals to be met all contribute to task complexity (Berry, 1995).

> Complex problem solving is the successful interaction with task environments that are dynamic (i.e., change as a function of the user's interventions and/or as a function of time) and in which some, if not all, of the environment's regularities can only be revealed

by successful exploration and integration of the information gained in that process (Buchner, 1995).

Complex problem solving is the task of optimizing one or more target variables of a system by a series of decisions. The system consists of several variables, there are several alternative actions. Information about the system or system states is incomplete (e.g., not available or probabilistic) or delayed. A time component may be involved (Huber, 1995).

Although the definitions addressed here are different from each other, they describe a complex problem as a product of cognitive processes interacting with outside dynamic environment. In addition, the elements of the problem are interrelated with each other. Quesada, Kintsch, & Gomez (2002) also proposed that a complex problem is a situation in which the most variables are not just related with each other in a one-to-one manner. In other words, the elements of the problem are interconnected and complex.

Kluwe (1995) argued that a complex problem can be either a class consisting of a number of interrelated components in referring to the task environment or an operator system requiring a large number of different cognitive operations for searching the information and finding the solution through the problem space in reference to the problem space. In addition, he mentioned that the complex problem can be decomposed of several small units of problems (Frensch & Funke, 1995b).

Albers (2002) argued that a complex problem is a real world problem, which requires problem solvers to make decisions in various ways, follow highly dynamic paths beyond a step-by-step process, adapt themselves to the complex problem, and consider solutions iteratively. He also proposed a trait of a complex problem is that complex problem solving is non-linear, which means that (1) paths of actions are unpredictable; (2) nuanced judgment and interpretations are required; and (3) interrelated relations yield many potential solutions. Funke (1991) argued that the characteristics of complex problems can be addressed by the one of the following features. A complex problem has intransparency, which means that a complex problem does not allow problem solvers to infer the underlying state within the problem directly. A complex problem has polytely, which means that it enables problem solvers to search and find many goals in the problem.

The complex problem is characterized by the number of elements of the problem as well as their connectivity pattern. The complex problem changes dynamically over time, leading problem solvers to represent the problem in various ways while they encounter the problem. Finally, complex problem solving is time-delayed effort, which means solvers can't get the result immediately. It is not only possible to assume how the problem occurs, but it is also possible to conjecture how a partial solution impacts the problem after problem solvers apply their solution strategies.

In the following, some examples of complex problems are addressed to outline the features of complex problem solving across the domain. In the first example, three notes are important to consider. First, the problem is about how a vice-president of a company reacts to the response of a customer's opinion. When problem solvers meet the problem, they should consider what the elements of problem are and how one element influences one another. Second, the problem is a story problem in which solutions and goal states vary. Third, the problem is expected to cause problem solvers some difficulties to keep track of how one element affects the other elements. It is critical for the problem solver to consider the relations among elements of the problem.

> The vice-president of a butterfat manufacturer received a call from a customer of her midwestern plant. Some recent bags of butterfat that the customer received have turned rancid during the manufacture of various food products. The discrepancy between the actual level of performance – some of the butterfat was turning bad – and the expected standard of performance was the vice-president's indication that a problem existed. She defined the problem in terms of a deviation from the expected standard, thus defining the problem as "some bags of butterfat produced in the midwestern plan turn rancid before they should…. However, why would only the one customer be affected?… Having found the source of the problem, the vice-president decided to stick with the new freezer because it was more cost-effective, but to change the way the bags were handled by the customer. Instead of building the bags into a solid cube, the bag handlers were instructed to leave at least one inch of space between the columns. A subsequent test using temperature probes showed that the space between columns resulted in all bags being frozen completely. The vice-president finished by calling the customer to explain the

problem and how it was corrected. (A managerial problem adapted from Wagner, 1991, pp. 161-162).

A man once offended a fortune teller by laughing at her predictions and saying that fortune telling was all nonsense. He offended her so much, in fact, that she cast a spell on him which turned him into both a compulsive gambler and in addition a consistent loser. That was pretty mean. We would expect the spell would shortly have turned him into a miserable, impoverished wreck. Instead, he soon married a wealthy businesswoman who took him to the casino everyday, gave him money, and smiled happily as he lost it at the roulette table. They lived happily in just this way ever after. Why was the man's wife so happy to see him lose? (A story problem cited from Hayes, 1989, p. 13)

Messrs. Downs, Heath, Field, Forest, and Marsh – five elderly pigeon fanciers – were worried by the depredations of marauding cats owned by five not less elderly ladies, and, hoping to get control of the cats, they married the cat owners. The scheme worked well for each of them so far as his own cat and pigeon were concerned; but it was not long before each cat had claimed a victim and each fancier had lost his favorite pigeon. Mrs. Downs's cat killed the pigeon owned by the man who married the owner of the cat which killed Mr. Marsh's pigeon. Mr. Downs' pigeon was killed by Mrs. Heath's cat. Mr. Forest's pigeon was killed by the cat owned by the lady who married the man whose pigeon was killed by Mrs. Field's cat. Who was the owner of the pigeon killed by Mrs. Forest's cat? (A complex problem cited from Hayes, 1989, p. 15)

Situatedness

Description. A growing interest has emerged in the role of situatedness in learning and cognition (Gero & Kannengiesser, 2000; Jonassen, 2003b; Peffat & Gero, 1999). Rohlfing, Rehm, & Goecke (2003) defined situatedness as a specific situation in which task oriented behavior (i.e., problem solving activity) occurs. Hegarty, Mayer, and Monk (1995) argued that situatedness is concerned with the situation described in the problem. Peffat & Gero (1999) argued that situatedness implies "where you are, when you do, and what you do." (p. 1). Situatedness can also be denoted as the meaningfulness of the situation as interpreted through a learner's prior knowledge and experience. It has been claimed that whether situatedness is meaningful or not is interpreted and constructed through a problem solver's prior knowledge (Albers, 2002; Confrey, 1991; Jonassen, 2003b; Roth & McGinn, 1997).

Inferred from their assertions, it can be argued that situatedness denotes the meaningfulness of the situational problem as interpreted through a learner's prior knowledge and experience while problem solvers encounter the problem. Situatedness is characterized by three general traits, which are interactivity, learning, and goal-directedness (Gero & Kannengiesser, 2000; Peffat & Gero, 1999; Roth & McGinn, 1997). Therefore, something that is situated means the situation interacts with other factors to learn and achieve the goal.

It has been noted that situatedness is closely engaged in problem-solving performance (Jonassen, 2001). Peffat & Gero (1999) argued that situatedness implies that something is interacting with the environment in order to reach a goal. The attempt to actively engage in the social and cultural environment to complete a problem solving can be construed as situatedness reflecting the contextuality of the situation (Lindblom & Ziemke, 2002). Roth and McGinn (1997) argued that the situational characteristics influence the problem representation because they represent the contextual elements nested in the problem. That is, recognizing that there is a problem to be solved may have to do a great deal with situatedness.

In addition, Chi, Feltovitch, and Glaser (1981) argued that problem solvers, especially novice problem solvers, tend to classify physical problems based on the situatedness of the problem. The more situated the problem turns out to be, the easier it is for the problem solver to represent the problem, and therefore, the possibility to solve the problem successfully increases. Depending on the levels of situatedness, the problem can be either a contextualized situation problem that happens around us everyday or a decontextualized problem that occurs just in a laboratory or a textbook in a classroom.

<u>The decontextualized situation problem.</u> There are two classes of problems in terms of situatedness: those that are decontextualized situation problems, which lack meaningful contextuality within themselves, and others that are contextualized situation problems, which depend highly on the dynamics and flexibility of the external environment (Arlin, 1989; Luszcz, 1989; Meacham & Emont, 1989). In the case of the decontextualized situation problem, the range of information and procedures to solve the problem may be described explicitly. Though the possible methods to solve the problem are hidden implicitly in the problem, it is easier to search and find necessary information for solving the problem than in the contextualized

situation problem. The basic characteristics of the decontextualized situation problem rely on whether (1) the story context exists; (2) the problem emerges from a specific domain; (3) decision making is time-dependent; (4) all elements are related to the situation; (5) solutions are generally accepted; and (6) the problem motivates the solvers to solve it (Albers, 2002; Dabbagh, 2002; Jonassen, 2000, 2003b; Meacham & Emont, 1989; Peffat & Gero, 1999; Smith, 1991; Voss & Post, 1988; Wood, 1983).

The story context refers to whether there is a story in the problem. The story is a flow, which enables problem solvers to find and represent the problem as well as generate and evaluate the problem. The decontextualized situation problem has no story, which explains where and why this problem comes to the problem solver. The decontextualized situation problem does not focus on specific knowledge domain. For example, addition and subtraction type problems can be applied in mathematics, physics, or economics if they just require the problem solvers to calculate the problem solution (Jonassen, 2003b; Schraw et al., 1995).

Decisions may not be made at the correct moment in relation to the outside environment in the decontextualized situation problem. All elements of the decontextualized situation problem, which are the initial state, the goal state, constraints, and operators, are not situated, the result being that they are abstract and isolated. In the problem, paths to acquire solutions and obstacles to solution are clear so that solutions may be accepted among problem solvers rather than a contextualized problem. However, the decontextualized problem may be challenging to problem solvers. Sometimes, lack of clear paths to solutions may not stimulate the interest of problem solvers.

Some support for traits of decontextualized problems may be found by turning to two quite simple examples of problem solving. They may direct our attention to the definition of decontextualized situation problem.

1. What is the difference between using Listservs and e-mail to connect with the Internet?
2. In what ways is searching the Internet different from searching a database such as ERIC?
3. Which parts of a website are most helpful when conducting a review of research? Why?

4. What is the difference between using subject directories and search engines to locate the information on the Web?

(Internet problems cited from McMillan, 2000, p. 99)

Listed here are descriptions of behaviors. Use the following options to identify the category each behavior represents:

A: Declarative knowledge   B: Procedural knowledge   C: Motor skill   D: Attitude

(A learning outcome problem cited from Oosterhof, 2001, p. 35)

20 is related to 30 as 10 is related to ___________?

a. 5   b. 25   c. 60   d. 15   e. 10

(A math problem cited from Whimbey & Lochhead, 1991, p. 4)

The contextualized situation problem. In opposition to the decontextualized problem, the contextualized problem places emphasis on situatedness. A number of studies such as Sinnott and Cook (1989) have attempted to generate contextualized situation problems and investigate how they impact problem-solving performance (Jonassen, 2003b). The contextualized situation problem refers to a context of action, which arises not in the abstract, but in practical and meaningful situations (Meacham & Emont, 1989). Sinnott and Cook (1989) preferred to use terms such as “everyday,” “naturalistic,” or “happening all the time” as descriptors when they define the problem. Luszcz (1989) delineated the role of the context in problem solving and argued that the context of the problem is concerned with its definition, solution, as well as a philosophical view including how to see the problem.

Zimmerman and Campillo (2003) distinguished the formal context of the problem from the informal context of the problem. They mentioned the importance of contextualized problem-solving in daily life. An informal context, which is the same concept as contextualization, functions as a factor that affects solution generation, goal orientation, motivation, and strategy development while problem solvers make efforts to solve the problem. Finally, they argued that the decontextualized problem eliminates many essential processes for solving problems and provides a critical opinion that problem solvers may not even perceive in the presence of the problem.

The contextualized situation problem has a story and emerges from a specific domain. Therefore, the problem is realistic and more natural than the decontextualized situation problem. Problem solvers should respond to the problem immediately because a decision should be made at the correct moment in conjunction with the consideration of the needs of the external environment. All elements of the problem are highly interrelated and interact with each other to achieve the goal. Solutions remain fuzzy. There is no absolute correct answer, nor paths to approach the goal state. The contextualized problem gets the problem solver motivated to perceive the problem as urgent, important, and an exciting activity (Zimmerman & Campillo, 2003). In summary, the contextualized problem subsumes these assumptions in their features and structures.

In the following, three examples of contextualized situation problems are provided. The main concerns of the examples are with how feasible it is for each problem to occur in everyday life and how often the problem solver meets the problem at home or in the workplace. The first problem is a grocery shopping scenario with which people are very familiar.

> You are having three couples over for brunch on Sunday morning. Because of work obligations, you have left everything until the last minute. It is now Saturday evening at 8:45 pm, and the store closes at 9:00 pm. You remember on your way to the store that you are low on cash because you paid the telephone bill yesterday. You look in your wallet and find only $35.00. Do the best you can to purchase the items you need for brunch tomorrow.
> (Grocery shopping problem cited from Rebok, 1989, p. 111)

> Suppose that you have a choice between a safe investment which yields a sure 25% return and a risky investment which gives you an even chance of either tripling your money or of losing it. Which investment is best?
> (A practical decision-making problem cited from Hayes, 1989, p. 14)

> "When Tom comes home, he wants to relax and unwind by quietly reading the news. He is stressed by the unsolved problems of his day and finds relief through forgetting them. His wife, Mary, also wants to relax from her stressful day. She, however, wants to find relief by talking about the problems of her day. The tension slowly building between

them gradually becomes resentment. Tom secretly thinks Mary talk too much, while Mary feels ignored. Without understanding their differences they will grow further apart."

(A stress problem cited from Gray, 1992, pp. 29-30)

Information Richness

Description. Traditionally, problem-solving research has not been much interested in the information nested in the problem beyond a consideration of factors affecting problem-solving performance (Habertlandt, 1997; Quesada et al., 2002). Though there is a limited amount of research that has been done on information richness in problems, researchers have begun to understand that information about the problem plays a role in problem representation, searching, generation of solutions, evaluation of the solutions, and advocating judgment (Voss, 1988; Voss & Post, 1988). Thus, their interests in information richness of problems has shifted from specific influential factors to a general factor that they had not paid much attention to previously. Confrey (1991) described problem solving as the problem solver's activity of putting information about the problem together in a new way. His focus appears to concern the information richness of the problem.

In addition, Quesada, Kintsch, and Gomez (2002) distinguished the knowledge-lean problem with the knowledge intensive problem, which can be also called a knowledge-rich problem. According to their distinction, either if fine-tuned knowledge is necessary to solve the problem or if problem solvers can't solve the problem with only the information presented implicitly or explicitly in the problem, the problem can be a sort of knowledge-lean problem. However, if problem solvers have no difficulties in solving the problem without specific knowledge that is required for the problem, this problem is named a knowledge-intensive problem. Another way to investigate the importance of information richness of the problem is to regard each element of the problem as one part of information represented in the problem (Greeno, 1978; Jonassen, 2003b; Roth & McGinn, 1997).

If one of the elements in the problem is vague or unclear, insufficient information represented in the problem may be a possible reason why problem solvers have a hard time understanding elements of the problem. Difficulties in searching potential solutions of the problem may also be attributed to insufficient information represented in the problem. Therefore, information richness of the problem can promote successful problem-solving performance. It can be argued that high performance in problem solving could be attributed to the quantity of information addressed in a problem. Habertlandt (1997) argued the some problems lack of information about rules, operators, and solutions, which become obstacles preventing successful problem solving.

The information-lean problem. There is an implicit agreement among some researchers that, if problem solvers have a lot of prior knowledge, information lacking in the problem can be supplemented either through the addition of elements or through inferential processes (Taylor & Dionne, 2000; Wood, 1983). However, when problem solvers confront a problem, they start problem representation based on the information employed in the problem. Successful problem representation depends on the sensitivity of problem solvers to the condition that they are not satisfied with the amount of knowledge presented in the problem (Gick, 1986; Hayes, 1989; Voss & Post, 1988).

Basically, problem representation is established when the problem solvers select the information for defining the problem (Voss & Post, 1988). Thus, Jonassen (2000) argued that the function of problem representation is to extract the information from the problem and map the information onto prior knowledge. That is, if problem solvers don't find necessary information from within the problem statement, they may fail to retrieve prior knowledge from their knowledge structures.

The above assertions imply that a problem can be categorized as either a problem having much information for problem solving or a problem having little information, regardless of how much knowledge problem solvers have (Duch, 2001; Habertlandt, 1997). It is important to keep in mind that information nested in the problem is not a sufficient element to explain problem solving, but rather a necessary component to help problem solvers represent the problem, generate solutions, and search their tremendous accumulated knowledge base. The information-lean problem is defined as a problem that has insufficient information for solving the problem (Andre, 1986; Arlin, 1989; Simon, 1978).

In other words, information-lean problems are those problems whose initial states, goal states, solution paths, and constraints may not be clear or may even have been omitted, preventing problem solvers from planning, searching, and evaluating problem solving processes (Albers, 2002; Duch, 2001; Jacobs et al., 2003; Mennecke, Crossland, & Killingsworth, 2000). The following examples provide typical characteristics of information-lean problems. One of the main reasons why problem solvers may not solve the problem is the insufficiency of information that the problem statement represents. Such insufficiency is an obstacle for problem solvers to negotiate the starting state, referred to as initial state, to another possible state that the problem could be in.

> 150 People received the drug and were not cured.
> 150 people received the drug and were cured.
> 75 people did not receive the drug and were not cured.
> 300 people did not receive the drug and were cured.
> Evaluate the effectiveness of the drug based on this information.
> (Information-lean problem cited from Stanovich, 2003, p. 295)

> Describe in detail your best strategy for teaching 5th grade students in a regular classroom the mathematics concept of either "Ratio/Proportion," or just "Ratio" or just "Proportion." Create a specific problem-solving activity focused on the mathematics concept which you choose. Include the rationale for your choice of activity. Your 5th grade students have had relevant experiences with the following: Develop whole number sense and understanding of the numerical system. For example, they are able to develop strategies to solve problems involving large numbers. …Develop number sense and understanding of fractions, mixed numbers, and decimals to solve problems. For example, they are able to combine and separate fractional amounts with concrete objects, and investigate mixed numbers, proper and improper fractions using manipulative and graph paper.
> (A mathematical problem cited from Kim & Sharp, 2000, p. 338)

<u>The information-rich problem.</u> In contrast, the information-rich problem can be defined as a problem composed of clear information regarding the initial state, the goal state, constraints, and operators of the problem. Early research in problem solving focused on problem finding, which is to recognize if there is a problem to be solved, and to represent the problem, which is to understand the nature of the problem (Simon, 1978). In a series of early studies, it has been argued that when the problem is not found or adequately represented, such failures can evidently be attributed to the lack of information richness in the problem statement

(Bauer, 1991; Jonassen, 2000, 2003b). The richer the information nested in the problem, the easier problem solvers find it to represent the problem.

However, there was a reaction against the assertion that information richness represented in the problem per se is helpful for problem solving. Too much information may confuse problem solvers in choosing useful information required for problem solving, as well as cause problem solvers to fail to solve the problem finally (Hayes, 1989). Despite the contrasting arguments, the benefit of information richness is increasingly emphasized among researchers.

The main criterion by which to distinguish information-rich problems from information-lean problems is (1) the existence of all the problem elements, which include the initial state, the goal state, operators and constraints; (2) the numbers of interruptions of information presentation; (3) the chucking of information within the presentation of the problem; and (4) the number of concept, rules, and principles required to solve the problem. Implicit configuration of each element in the problem can include the absence of information (Chi, 1985; Confrey, 1991; Greeno, 1978; Meacham & Emont, 1989; Polson & Jeffries, 1983). If all the elements of the problem can be identified explicitly, the problem can be thought of information-rich problem. The number of interruptions in information presentation can be regarded as obstacles hindering problem solvers from solving problems.

The more the interruptions, the greater the possibility that the problem solver fails to solve the problem (Pretz et al., 2003). If a problem has a lot of interrupted information, it can be regarded as an information-lean problem. The chunking of information is how the information is organized and represented in the problem. It is easier for problem solvers to find meaningful information if the information is located in order or closely (Hayes, 1989). The information-rich problem can be characterized by this chunking of information. If cues to the relevant elements are dispersed throughout the problem presentation, the problem is not well chunked.

If, however, the relevant elements are coherently presented, the problem can be said to be well chunked. Finally, any useful information such as concepts, rules, and principles can be posed in the problem statement as possible operators or cues. If a problem depends on significant information about these, they can be distributed into the information-rich problem. To illustrate the information-rich problem, the following are two examples that present all the elements, have limited interruptions, and present well-organized information and potential operators.

> Sales agents who work for the Acme Wig Company are assigned to a different city each year. Henry began working for Acme in New York in 1965, and in the succeeding 4 years worked in Minneapolis, New Haven, Youngstown and Charleston, in that order. Martha worked for Acme in New Haven in 1963, and in succeeding years worked in New York, Charleston, Minneapolis, and Youngstown. Fred worked for Acme in Charleston in 1967; the previous 2 years he had worked first in New Haven and then in Minneapolis. John worked in Charleston in 1968. Before that he was in New Haven, before that Youngstown, and before that New York. Which Acme sales agents were in New Haven in 1967? Which ones were in Minneapolis in 1966?
> (A math problem cited from Whimbey & Lochhead, 1991, p. 61)

> You are standing by the side of a river which is flowing past you at the rate of 5 mph. You spot a raft 1 mi. upstream on which there are two boys helplessly adrift. Then you spot the boys' parents 1 mi. downstream padding upstream to save them. You know that in still water the parents can paddle at the rate of 4 mph. How long will it be before the parents reach the boys?"
> (A speed problem cited from Hayes, 1989, p. 25)

This chapter investigated and discussed the theory and empirical findings of research that inform the analysis of factors that affect problem-solving performance as problem characteristics in terms of structuredness, complexity, situatedness, and information richness. The features of problems are independent. Thus, it is assumed that they can account differently for the likelihood or probability that problem solvers' will solve the problems. However, the basis of reviews of literature conveying previous study results and theoretical rationales regarding the characteristics of the problem have not precisely specified how these attributes may relate to problem-solving performance, nor has it been established the existence or absence of causal relationships among these variables that may influence problem-solving performance.

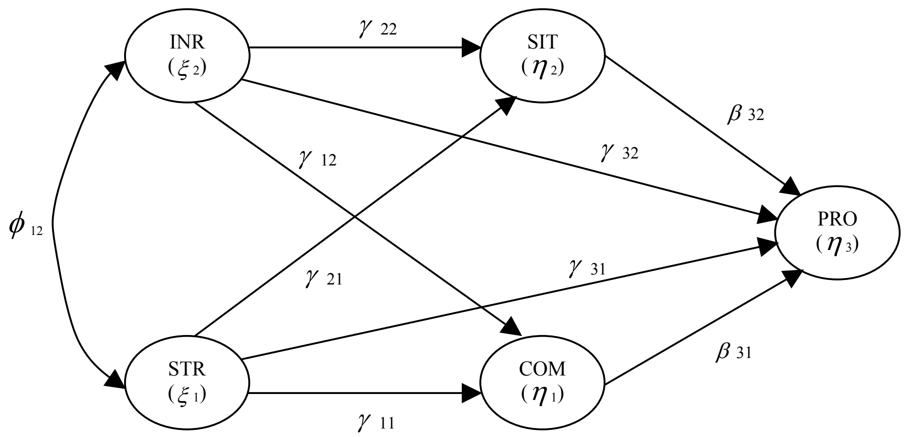
In prior research, problem characteristics have been defined and measured mostly in terms of learners' perceptions rather than independent analyses or expert ratings of the characteristics. Therefore, this study also focused on learner perceptions of problem characteristics. In relation to the problem-solving performance, this study selected a set of mathematical word problems for the dependent measure because word problem solving has commanded a great deal of by many researchers in the math education field. In the next chapter, eight hypotheses are constructed and addressed to examine the dependent measure of problem-solving performance from four perceived attributes of problem characteristics.

CHAPTER 3

HYPOTHESES

The study was designed to investigate the effect of problem characteristics in terms of perceived structuredness, complexity, situatedness, and information richness on mathematical problem-solving performance. In particular, "How do perceived problems' structuredness, complexity, situatedness, and information richness affect mathematical problem-solving performance?" This study used a multivariate design to examine the relations among variables through the use of Structural Equation Modeling (SEM) procedure. Specifically, this study attempted to examine a structural equation model, which identifies if the characteristics can be possible causes of problem-solving performance as well as explores the relationships among these variable attributes of problems that may account for the problem-solving performance.

The model of problem characteristics presented in the study is a recursive model, which is diagramed in Figure 2 below. To examine the effect of problem characteristics in terms of structuredness, complexity, situatedness, and information richness on mathematical problem-solving performance, eight hypotheses were constructed and addressed on the basis of reviews of literature conveying previous study results and theoretical rationales.



ξ_1: Structuredness ξ_2: Information richness η_1: Complexity
η_2: Situatedness η_3: Problem-solving performance

Figure 2. Hypothetical causal model

1. Learners' perception of structuredness has positive direct and indirect effects on successful problem solving performance.

Many researchers have placed emphasis on the positive effect of perceived structuredness on problem-solving performance (Allaire & Marsiske, 2002; Brabeck & Wood, 1990; Dabbagh, 2002; Dillon, 2000; Houdeshell, 2001; Jonassen, 2000; Sinnott, 1989; Voss & Post, 1988). Voss (1988) argued that the perceived structuredness of a problem influences a problem solver's problem solving process, from routine, automatic processes with which the problem solver is familiar to one of unexpected, controlled processes that he or she judges and decides. Moreover, perceived structuredness of the problem affects the representation process that is an essential step for successful problem solving (Brabeck & Wood, 1990; Duch, 2001; Jonassen, 1997; Polson & Jeffries, 1983; Rittle-Johnson & Alibali, 1999). Especially, the more structured problems are perceived by students, the more likely they are to solve the problem successfully (Polson & Jeffries, 1983; Rittle-Johnson & Alibali, 1999; Voss & Post, 1988).

2. Learners' perception of information richness has positive direct and indirect effects on successful problem solving performance.

Perceived information richness is expected to promote successful problem-solving performance. Presumably, high performance in problem solving could be attributed to the quantity of information addressed in a problem. Habertlandt (1997) argued that some problems lack of information about rules, operators, and solutions, which become obstacles preventing successful problem solving.

3. Learners' perception of complexity has a negative effect on successful problem solving performance.

Perceived complexity is presumed to affect successful problem solving negatively (Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003). The more complex a problem is, the harder it is for a problem solver to find a solution. For example, Jacobs, Dolmans, Wolfhagen, & Scherpbier (2003) conducted a study examining students' preferences toward a complex problem. The result showed that increased complexity made it difficult for them to choose one of the best methods to solve the problem and high percieved complexity led to failure of the problem solving.

4. Learners' perception of situatedness has a positive effect on successful problem solving performance.

Perceived situatedness is also closely related to successful problem solving (Jonassen, 2001). Peffat and Gero (1999) posited that perceived situatedness implies that something about the problem interacts with the environment to affect the problem solver's ability to continually accomplish goals. The attempt to actively engage problem solvers in social and cultural environments to complete problem solving can be led by situatedness, reflecting the contextuality of the situation (Lindblom & Ziemke, 2002). The more situated the problem turns out to be, the more actively the problem solver participates in problem solving, and therefore, the probability of solving the problem successfully increases.

5. Learners' perception of the structuredness attribute has a negative effect on the perception of the complexity attribute of the problem.

Some researchers such as Jonassen (2000, 2003) have claimed that the structuredness of a problem has a close relationship with complexity, which seems to overlap invariably, although he emphasized that these two factors are sufficiently independent. However, other researchers such as Dabbagh (2002), Duch (2001), and Jonassen (2000) have argued that structuredness has a negative effect on complexity. That is, the more structured the problem becomes, the less complex the problem becomes. Thus, the hypothesis is that structuredness has a unidirectional negative effect on the complexity of problems.

6. Learners' perception of the information richness attributes has a positive effect on the perception of the situatedness attribute.

A series of previous studies such as that of Peffat and Gero (1999) reveal that perceived situatedness is captured by information in relation to the situation where the problem occurred. Information represented in the problem plays, in part, as a clue that supports a problem solver to be active and sensitive to a specific environment. For example, if a problem solver is provided with a problem having relevant information, it may stimulate the problem solver to keep track of situatedness in light of problem solving goal.

7. Learners' perception of the structuredness attribute has a negative effect on the perception of the situatedness attribute.

This hypothesis is based on previous studies that perceived situatedness is affected by how well the problem is structured (e.g., Allaire & Marsiske, 2002; Jonassen, 1997; Polson & Jeffries, 1983; Schraw, Dunkle, & Bendixen, 1995; Sinnott, 1989; Voss & Post, 1988). That is to say, if a problem appears to be well-structured, it allows a problem solver to think that the problem is abstract and decontextualized. Well-structuredness deemphasizes the importance of the situational context during problem solving and requires the problem solver to represent the problem without considering situatedness by applying well-defined rules and answers (Jonassen, 2000; Hong, 1998). Whereas ill-structuredness has a tendency to increase the level of situatedness, if a problem appears in ill-structured form, the problem tends to be more situated (Jonassen, 2003b). Thus, it is hypothesized here that the structuredness negatively influences the situatedness in which the problem exists.

8. Learners' perception of the information richness attribute has a negative effect on the perception of the complexity attribute.

There are two possibilities for the way perceived information richness has a relationship with perceived complexity. It has been assumed that if the information nested in a problem is rich, the level of complexity decreases because specific information can be found from within the problem space, and the richness enables a problem solver to make complicated components of the problem clearer (Voss, 1988; Voss & Post, 1988). Perceived information richness has a negative effect on complexity. Thus, this study assumes that greater richness enables better problem-solving performance by decreasing the complexity.

However, the relation between the information richness attribute and structuredness attribute is not hypothesized in a reason that the previous studies have not shown any theoretical and empirical evidences for it.

CHAPTER 4

METHOD

Subjects

The subjects in the study were recruited from undergraduate students registered in introductory courses in geography at a large southeastern university in the United States. The subjects in geography courses were selected to include as large a number of subjects and as wide a range of backgrounds as possible. The subjects were those who were willing to participate in the study voluntarily. They were assured of the confidentiality of their responses to the study. In addition, subjects completed an informed consent form before the experiment took place.

Though it is difficult to find sample size requirements in SEM, the minimum sample size that is generally accepted and recommended is 200 (Hair, Anderson, Tatham, & Black, 1998). Brecker (1990, cited from Kline, 1998), who surveyed 72 studies published in psychology journals, reported that medium range of sample size across these studies was 198. Thus, over 200 subjects were selected to allow for subject attrition.

Variables

There are two exogenous variables and three endogenous variables in the model. The two exogenous variables are constructs that act as a cause for other variables in the model and are not explained by the model. Three endogenous variables are constructs that are dependent variables in causal relationships and are explained by the model.

The exogenous variable is the perceived structuredness (ξ1) that measures how clear the problem's initial state, goal state, solutions, and constraints are to the problem solver. The other exogenous variable is perceived information richness (ξ2) of the problem under consideration that measures the extent to which specific information for solving the problem is provided.

In addition to problem-solving performance, two endogenous variables are variable attributes of problem characteristics. Perceived complexity (η1) measures the degree to which the problem's initial state, goal state, possible solutions, and constraints are interwoven and interact with each other. Perceived situatedness (η2) measures the extent to which a problem reflects contextuality of specific situation. The endogenous variable, problem-solving performance (η3), measures the subjects' mathematical problem-solving performance. This variable is also an endogenous variable because it is caused by other variables in the model.

Materials

Two instruments comprised of several previously used and newly developed measures were used to examine the perception of problem attributes and problem-solving performance. The complete measures can be seen in Appendix A and B. The following instruments were used to collect the data for the study.

Perception of problem attributes measure

The items to comprise a survey measuring subjects' perceptions of problem attributes were generated based on existing instruments and the review of literature. First, seven survey items (#1-7) measuring the perceived structuredness of the problem were taken from two existing perception measures developed by Jacobs, Dolmans, Wolfhagen, & Scherpbier (2003) and Houdeshell (2001) (See Appendix A). For example, Item 4 on the instrument, which is designed to examine the number of solutions in the problem, states: "The problems have a single correct answer."

The possible range of item scores is from one to five: 1 indicates that subjects strongly disagree with the statement of the item and 5 indicates that subjects strongly agree with the statement of the item. A rating of 3 indicates that subjects are not sure about the statement of the item. The reliabilities of the two original survey instruments that have 12 and 15 items respectively were .60 and .82 (Houdeshell, 2001; Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003). Evidence of content validity of the inventory is described through the literature review, which provides the items on the instrument with a scholarly basis in the literature review. Evidence of internal reliability for structuredness is reported through the consistency with which subjects indicate items measuring structuredness. Cronbach's alpha that addresses how well a set of items measure a single unidimensional construct is used as a measure of internal reliability. The alpha level is presented in the results chapter.

Second, seven survey items were taken from existing scales (Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003; Lee & Heyworth, 2003; Rauterberg, 1996) to investigate the subjects' perception of the problem' complexity (items 8-14). For example, Item 12 on the instrument, which is designed to examine the combination of elements of the problem, states: "Many concepts, rules, and principles are put together in the problem." The subjects indicated the level of agreement with the statement by circling 1 through 5. As indicated above, 1 indicates that subjects strongly disagree with the statement of the item and 5 indicates that subjects strongly agree with the statement of the item. The reliability of the instrument items containing 20 items developed by Lee and Heyworth (2003) was .81. Evidence of content validity of the inventory is described through the literature review, which provides the items on the instrument with a scholarly basis in the literature review. Evidence of internal reliability for complexity is reported through the consistency with which subjects indicate items measuring complexity. Again, Cronbach's alpha for internal reliability is reported and presented in the results chapter.

Third, seven survey items measuring situatedness were devised from previous studies regarding the implications of situatedness on problem-solving performance. Previous studies include the work of several researchers (e.g., Gero & Kannengiesser, 2000; Lindblom & Ziemke, 2002; Peffat & Gero, 1999; Rohlfing, Rehm, & Goecke, 2003) as analysis frameworks and suggestions for enhancement of situatedness in classroom settings. Items 15 through 21 investigate the subjects' perception of the problem' situatedness. For example, Item 21 on the instrument, which is designed to examine the multiple interpretation of the problem in a specific situation, states: "The problems can be interpreted differently by the situation where the problem solver experiences it." The possible range of scores is the same as that of structuredness and complexity. Evidence of content validity of the inventory is described through the literature review, which provides the items on the instrument with a scholarly basis in the literature review. Evidence of internal reliability for situatedness is reported through the consistency with which subjects indicate items measuring situatedness. Cronbach's alpha for internal reliability is reported and presented in the results chapter.

Fourth, seven items measuring information richness were devised from instrument items developed by Owens Jr (1989), and Voss (1988), as well as results of protocol analysis reported by Chi & Glaser (1985), Taylor and Dionne (2000), and Swanson (1990). Items 22 through 28 investigate the subjects' perception of the problem's information richness, For example, Item 27 on the instrument, which is designed to examine the necessity of specialized information for problem solving, states: "The problems require little specialized knowledge." The reliability of the survey instruments containing 20 items previously developed by Owens Jr. (1989) was .74. The possible range of scores is same as that of structuredness, complexity, and situatedness. Evidence of content validity of the inventory is described through the literature review, which provides the items on the instrument with a scholarly basis in the literature review. Evidence of internal reliability for information richness is reported through the consistency with which subjects indicate items measuring information richness. Cronbach's alpha for internal reliability is reported and presented in the results chapter.

Problem-solving performance measure

Problem-solving performance was measured by fifteen test items revised from an existing word problem solving set, namely, Whimbey Analytical Skills Inventory (WASI) (Whimbey & Lochhead, 1991). The test items are commonly used in school mathematics and in college entrance exams. This test consists of verbal reasoning problems, analogy problems, and word problems. Two mathematics teachers reviewed WASI items and selected and revised fifteen test items from the word problem set. The teachers examined the format and difficulties of the items for the problem-solving performance measure to determine if each problem could be generally accepted as mathematical word problems in math class.

The format of each problem is an essay item to exploit the advantage of measuring the performance effectively (Oosterhof, 2001) (See Appendix B and C). For example, one of the problems states: "A certain ball, when dropped from any height, bounces one-half the original height. If it was dropped from 80ft and allowed to bounce freely, what was the total distance it traveled when it hit the ground for the third time?" Another problem states: "A car started on a trip from city X to city Y which is 120 mi away. It ran out of gas one-quarter of the way through the last third of the trip. How many miles did it travel before running out of gas?" The subjects had to show their work in solving the problem and provide a specific answer.

The score for each problem was calculated by the average score of the two mathematics teachers who used a rubric to judge the correctness of each answer. The scoring rubric was based on four criteria suggested by Sweller (1988): (1) correct; (2) partially correct; (3) partially incorrect; and (4) incorrect. The score was therefore assigned based on both the problem-solving process and the correct answer. A scoring system used by Owens Jr (1989) was adapted for use in this study. In the scoring system, subjects were assigned a score of 5 if they solved the problem correctly. Subjects were assigned a score of 3 if they solve the problem almost correctly. Subjects received a score of 1 if they solved the problem almost incorrectly. Finally, subjects received a score of 0 if they solve the problem totally incorrectly. Therefore, a score for the problem-solving performance measure was obtained by averaging the individual scores on the 15 problems. Thus the total possible score on the problem-solving performance measure was 5.

Procedure

The study took place in a regularly scheduled geography class at a large southeastern university. The instructor of geography class allowed the researcher to enter the class for the research. The subjects were provided an informed consent form to grant voluntary inclusion of their data in the study. The informed consent form (Appendix E) tells the subjects that the purpose of study is to investigate the effect of a problem's characteristics on problem-solving performance (Appendix D). All subjects were told to participate in the activities of the experiment actively. They were also told the procedures that they should follow and times that they could spend during the experiment.

The researcher explained the general guidelines and schedule of the study to the subjects and then handed out a sheet of paper containing the fifteen problems. Subjects were told to read all the problems carefully for 3 minutes (Appendix B). Then, the inventory for estimating the perceived structuredness, complexity, situatedness, and information richness of all the problems was administered to the subjects. The subjects spent about 10 minutes to complete the survey items for the problems' characteristics.

Subjects then spent 45 minutes completing the problem-solving performance measure test performance (Appendix C). The subjects were provided two problems to a page to permit space to write whatever they wanted as they solved. Subjects were allowed to elaborate their ideas and write additional information that may come about during this cognitive process. The subjects were encouraged to ask the researcher when they didn't understand something with regard to the test.

Data analysis

This study adopts Structural Equation Modeling (SEM), which enables the researcher to estimate multiple and interrelated dependence relationships among variables. SEM can be defined as a multivariate technique examining causal inferences among endogenous and exogenous constructs within direct and indirect causal relationships. Hair, Anderson, Tatham, & Black (1998) explained that SEM is a statistical technique that combines some aspects of multiple regression examining dependence relationships and some aspects of confirmatory factor analysis testing whether a hypothesized model is consistent with empirical findings. Basic assumptions for SEM are (Loehlin, 1992; Tate, 1998): (a) the hypothesized model addresses the causal order of variables correctly, (b) the structural equation for each endogenous variable includes all variables that affect each endogenous variable, (c) each indicator should be normally multivariate distributed, and (d) linear relationships exist between indicator and latent variables, and between latent variables.

Typical steps of applying SEM in this study are (Tate, 1998): 1) specification of the initial model, which specifies a hypothesized model, confirms the identification of the model, and specify the procedures; 2) collection of data, which selects samples from the population of interest and collects measures of the model variables from the samples; 3) conduct of the preliminary analysis, which assesses missing data, identifies any outliers and case sensitive data influencing the data and reviews scatterplot and histograms under consideration of assumptions; 4) evaluation of the estimated model, which assesses overall test of model fit, searches for any violation of the correct functional fit assumptions, and decides if the initial model can be accepted or not; 5) revision of the model, which tests the improvement of model fit and revises the hypothesized model if the initial model is judged to be unacceptable, and 6) description of final model. The current study iteratively followed the steps mentioned above until the model fit the data, which means the variance and covariance logically implied by the model were the same as the observed variance and covariance.

The study employs a recursive model that assumes all arrows are unidirectional and unmeasured variables that are determinants of the endogenous variables. As seen in Figure 3 below, one variable causes other variables, meaning that the causal relationship does not allow feedback loop causations. Indeed, this model does not specify a measurement model that deals with latent variables because each latent variable in the measurement model has only one observed indicator. In conjunction with the latent variables and indicators in the model, the measurement error is considered and specified to identify more accurate causal relationships among variables.

Model identification was also considered to examine if there is sufficient information to allow estimation of all of the model parameters. In other words, this analysis was done to identify if the models is exactly identified or overidentified. If the initial model is underidentified, it should be modified to obtain identified model. There is a frequently used identification rule for SEM, which is t-rule (Tate, 1998). The t-rule (equal to [p+q+1][p+q]/2) states that the number of observed variances (denoted p) and covariances (denoted q) must be equal to or greater than the total number of model parameters being estimated.

The number of estimated model parameters in this study included two variances and one covariance for the two exogenous variables, eight path coefficients, and three variances of the equation errors, summing to a total of 14 parameters. The number of observed variances and covariances for the two exogenous and three endogenous variables was [(2+3+1)(2+3)/2]=15 items of information. The degree of freedom for the hypothesized model was 15-14=1. Therefore, this model was overidentified and an overall test of the model fit is possible, allowing possible falsification of the model.

According to the hypotheses listed earlier, the model has two exogenous latent variables. First, perceived structuredness stated as ξ_1 ("zi") has one directly observed indicator that is stated x_1 with one measurement error, δ_1 ("delta"). Next, perceived information richness stated as ξ_2 ("zi") has one directly observed indicator that is stated x_2 with one measurement error, δ_2. The variance and covariance among the latent exogenous variables are denoted with ϕ_{12}.("pi")

Three endogenous variables of perceived complexity, perceived information richness, and problem performance as latent variables are respectively denoted as η_1, η_2, η_3 ("eta"). There are three observed indicators stated from y_1 through y_3 with three measurement errors from ε_1 through ε_3 ("epsilon"). There are also three equation residuals of endogenous variables, which represent ζ_1, ζ_2, and ζ_3 ("zeta"). The variance and covariance among the residuals in the equations for the endogenous variables are labeled with ψ_{12}, ψ_{23}, and ψ_{13} ("psi").

The structural equations for the hypothesized measurement model are addressed below. The first and second equations representing two exogenous observed variables are:

$x_1 = \xi_1 + \delta_1$ Equation 1

$x_2 = \xi_2 + \delta_2$ Equation 2

The third equation through fifth equation for endogenous observed variables are:

$y_1 = \eta_1 + \varepsilon_1$ Equation 3

$y_2 = \eta_2 + \varepsilon_2$ Equation 4

$y_3 = \eta_3 + \varepsilon_3$ Equation 5

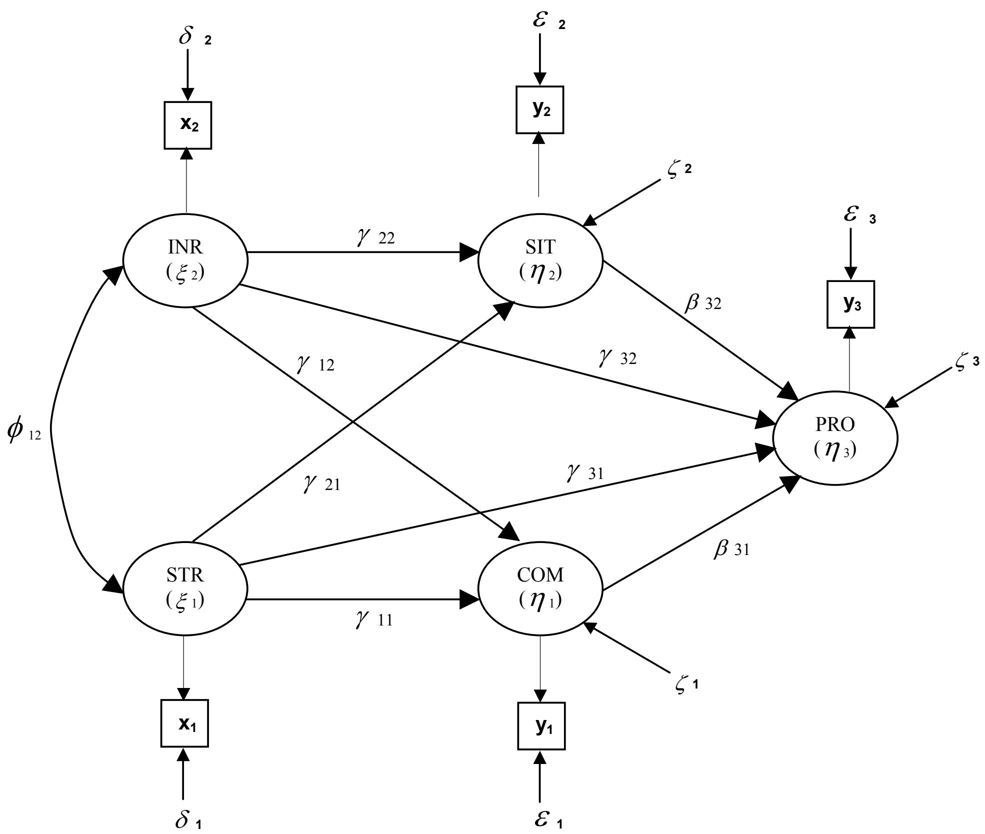
Structural equations in terms of latent variables are:

$\eta_1 = \gamma_{11}\xi_1 + \gamma_{12}\xi_2 + \zeta_1$ Equation 6

$\eta_2 = \gamma_{21}\xi_1 + \gamma_{22}\xi_2 + \zeta_2$ Equation 7

$\eta_3 = \gamma_{31}\xi_1 + \gamma_{32}\xi_2 + \beta_{31}\eta_1 + \beta_{32}\eta_2 + \zeta_3$ Equation 8

For the purpose of testing the hypothesis, LISREL VIII computer software developed by Joreskog and Sorbom (1996) was used to estimate and test SEM. This software enables the researcher to estimate relationships among variables with other variables and correlations and covariance among variables, measurement errors, etc. Furthermore, PRELIS software was used to process data prior to using LISREL software.



ξ_1: Structuredness ξ_2: Information richness η_1: Complexity
η_2: Situatedness η_3: Problem-solving performance

Figure 3. Hypothetical causal model with latent variables

CHAPTER 5

RESULTS

Preliminary analysis

Potential threats to the validity of the results from the study were detected and examined with two separate phases of preliminary analyses (Tate, 1998): (1) a review of descriptive data obtained from the experiment as well as examination and remedies of missing data, and (2) an assessment of assumption violations within SEM, which examines normality. The total number of subjects in the study was 219.

There is no evidence for the violation that all observations were not sampled from a multivariate normal distribution. Kolmogorov-Smirnov's test of normality with alpha level set at .01 for structuredness (z = 1.146, p> .01), information richness (z = 1.292, p>.01), complexity (z = 1.320, p>.01), and situatedness (z = 1.232, p>.01) indicated that all attributes of problems were distributed normally. In addition, Kolmogorov-Smirnov's test of normality with alpha level set at .05 for problem-solving performance (z = 1.162, p>.01) showed that the measure of problem-solving performance was distributed normally.

Results from the descriptive statistics addressed the mean and standard deviation of all indices and are displayed in Table 2 below. The possible neutral point score of each attribute measure was 3 (minimum score is 1, maximum score is 5). The data revealed that the mean scores for each perception on mathematical word problems were as follows: 3.220 (SD = 0.801) for perceived structuredness, 3.223 (SD = 0.668) for perceived information richness, 2.505 (SD = 0.627) for the perceived complexity, and 2.770 (SD = 0.698) for perceived situatedness. The data also revealed that the mean score for problem-solving performance was 3.224 (SD = 0.830).

Table 2. Descriptive Statistics

Variable	*M*	*SD*
Problem attributes		
Structuredness	3.220	0.801
Information Richness	3.223	0.668
Complexity	2.505	0.627
Situatedness	2.770	0.698
Problem-solving performance	3.224	0.830

Note: n=219, maximum score for each measure is 5.

Table 3. Correlation between latent problem attributes

	COM	SIT	PRO	STR	INR
COM	-				
SIT	0.151*	-			
PRO	-0.272*	-0.157*	-		
STR	0.122*	0.252*	0.484*	-	
INR	-0.393*	-0.257*	0.344	0.130*	-

Note: STR: Structuredness INR: Information richness COM: Complexity
SIT: Situatedness PRO: Problem-solving performance
* Statistically significant

The estimated correlations among the latent variables are shown in Table 3. Some of correlations were positive with magnitudes consistent with expectations based on the literature. The others were negative with magnitudes consistent with expectations based on the literature.

Test of SEM with latent variables

In the hypothesized model, the structuredness variable was represented by the indicator of x_1, information richness was represented by the indicator of x_2, complexity was represented by the indicator of y_1, and situatedness was represented by the indicator of y_2. Each indicator is same to the latent variables. A latent variable can be considered as a factor in factor analysis. The model predicting the effects of perception toward the characteristics of a problem on successful problem-solving performance was estimated, using LISREL VIII. It was found that the fit of the initial hypothesized model to the data was excellent. The parameter was estimated by applying the maximum likelihood estimates (MLE) fitting function.

The chi-square statistic ($X^2 = 2.086$, p=.149) resulted in a conclusion to fail to reject the null hypothesis that the fit of the initial model was correct. The root mean square error of approximation (RMSEA) was 0.071 with acceptable fit, which is the RMSEA>.05. The adjusted goodness of fit index (AGFI) was 0.943, which is taken as indicating acceptable fit. The comparative fit index (CFI) was 0.989, which was viewed as representing acceptable fit. The normed fit index (NFI) was 0.981, which is assumed to indicate acceptable fit. The incremental fit index (IFI) was 0.990, which is taken as indicating acceptable fit. The result (see Table 4) supported the acceptability of goodness of fit of the initial model to the data.

A more detailed assessment of the fit of the model was conducted by examining the difference between observed values and reproduced values for specific variances and covariances. Firstly, covariance residuals, which are the differences between the observed variance and covariances and the corresponding reproduced values, are addressed in Table 5. The largest covariance residual in Table 5 is 0.035 for the covariance of situatedness. In addition, the largest standardized covariance residual is 1.448. If the standardized residuals are less than 2.5 to 3.0, it doesn't indicate the misfit of the model. Therefore, the fit of model is not misidentified. Secondly, the modification index for identifying possible paths to be added to the model with poor fit was examined. However, data analysis result does not suggest modification of index. The absence of modification indices would be consistent with the model with good fit.

Table 4. Model Evaluation

Indices	Evaluation Criteria	Model Indices	Acceptable
Model fit	X2/df ≤ 3.0	2.086	*
RMSEA	≤ 0.08	0.071	*
AGFI	≥ 0.90	0.943	*
CFI	≥ 0.90	0.989	*
NFI	≥ 0.90	0.981	*
IFI	≥ 0.90	0.990	*

Note: RMSEA= Root Mean Square Error of Approximation; AGFI= Adjusted Goodness of Fit Index; CFI=Comparative Fit Index; NFI= Normed Fit Index; and IFI= Incremental Fit Index

Table 5. Variance and Covariance Residuals

	COM	SIT	PRO	STR	INR
COM	0.000				
SIT	0.035	0.000			
PRO	-0.008	-0.009	0.004		
STR	-0.003	-0.002	0.001	0.000	
INR	0.003	0.005	-0.002	-0.001	0.001

Note: STR: Structuredness INR: Information richness COM: Complexity
SIT: Situatedness PRO: Problem-solving performance

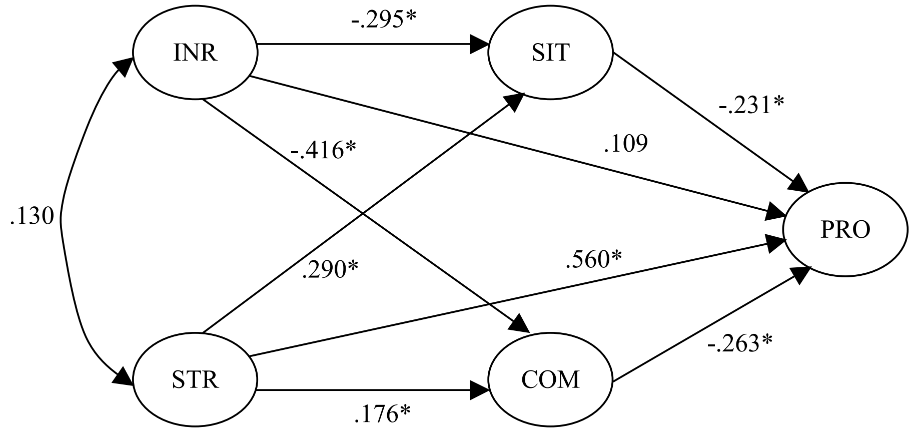
All the assessments of model fit discussed above were conducted for the reason that there is one missing path between perceived complexity and situatedness in the model. That is, the model is not a saturated model, which includes all possible paths. In the case of a saturated model, all of the reproduced variances and covariances are equal to the corresponding observed values. However, the missing path is consistent with the problem-solving theory. So, the theory is represented as much by the excluded path as by the included paths. Overall, the model is judged to be acceptable.

Table 6. Factor model loadings

Factor/ Variable	**Standardized Loading**	**Reliability (R^2)**
Structuredness (fixed)	0.881	0.776
Information richness (fixed)	0.844	0.713
Complexity (fixed)	0.848	0.719
Situatedness (fixed)	0.881	0.775
Problem-solving performance (fixed)	0.928	0.861

Any model representing a latent variable with a single observed indicator is underidentified (Hair, Anderson, Tatham, & Black, 1998; Tate, 1998). Fixing the value of the variance of the measurement error for the observed indicator can solve this problem. However, it is necessary to know the reliability of the indicator. The results for all the single indicator latent variables in Table 6 were fixed based on reliabilities, not estimated. The value of the variance of measurement error to be fixed in the model is computed as "observed variance (1-reliability)". Computations for each latent variable from the perceived structuredness to the problem-solving performance, using reliabilities 0.776, 0.713, 0.719, 0.775, and 0.861 respectively, result in the measurement error variance of 0.1438, 0.1280, 0.1104, 0.1093, and 0.0954. The model of Figure 4 is identified by fixing variance of all measurement errors.

The standardized loadings are the correlation of each indicator and the latent variable. These indicate that higher loading makes an indicator representative of a latent variable. Therefore, each indicator is representative to the each latent variable. The estimated standardized direct effects among the latent variables are presented in Figure 4. All estimated effects except for the effect of information richness on problem-solving performance ($z < 2.0$) were statistically significant.



Note: STR: Structuredness INR: Information richness COM: Complexity

SIT: Situatedness PRO: Problem-solving performance

* Effect statistically significant (z < 2.0)

Figure 4. Standardized direct effects for the revised causal model

The standardized direct, indirect, and total causal effects implied by the model are displayed in Table 7. All of the effects except for the effect of the perceived information richness on the perceived complexity were statistically significant. In terms of problem-solving performance, the determinant with the largest total causal effect (0.560) was structuredness, with most of the total effect due to the direct effect. The remaining determinants of problem-solving performance, complexity and situatedness, had total negative effects of -.263 and -.231, respectively. Approximately 42% of the variance of problem-solving performance was accounted for by these four determinants.

In terms of complexity, the determinant with the largest total causal effect (-.416) was information richness, with the direct effect. The remaining determinant of complexity, structuredness, had total effect of 0.176. Approximately 19 % of the variance of complexity is explained by these two determinants. With regard to situatedness, the determinant with the largest total causal effect (-.295) was information richness, with the direct effect. The remaining determinant of situatedness, structuredness, had total causal effect of 0.290. Approximately 15 % of the variance of situatedness is explained by these two determinants.

Table 7. Standardized causal effects for the model

Outcome	Determinant	Direct	Causal Effects Indirect	Total
Complexity (R^2= 0.185)	Structuredness	.176* (.088)		.176* (.088)
	Information Richness	-.416* (.092)		-.416* (.092)
Situatedness (R^2= 0.149)	Structuredness	.290* (.085)		.290* (.085)
	Information Richness	-.295* (.089)		-.295* (.089)
Problem-solving performance (R^2= 0.416)	Structuredness	.560* (.082)	-.113* (.045)	.447* (.076)
	Information Richness	.109 (.095)	.177* (.055)	.286 (.079)
	Complexity	-.263* (.089)		-.263* (.089)
	Situatedness	-.231* (.082)		-.231* (.082)

Note: The large sample standard error is shown in parentheses

* Effect statistically significant (*z* statistics >2)

In the first hypothesis, it was expected that learners' perception of structuredness would have a positive direct effect on successful problem solving performance directly and indirectly. This hypothesis confirmed that same result as expected in the hypothesis (i.e. direct effect: γ =.560 and indirect effect: γ =-.113). In the second hypothesis, it was expected that learners' perception of information richness would have a positive effect on successful problem solving performance. However, the result showed that insignificant direct effects and significant indirect effects were found to be significant between information richness and problem-solving performance.

In the third hypothesis, it was expected that learners' perception of complexity would have a negative effect on successful problem solving performance. The result supported the hypothesis (i.e. β =-.263). In the fourth hypothesis, it was expected that learners' perception of situatedness would have a positive effect on successful problem solving performance. However, the result did not support the hypothesis and in fact contradicted it (β =-.231). In the fifth hypothesis, it was expected that learners' perception of the structuredness attribute would have a negative effect on the perception of the complexity attribute of the problem. However, the result didn't support the hypothesis. (γ =.176), suggesting a positive effect instead.

In the sixth hypothesis, it was expected that learners' perception of the information richness attributes would have a positive effect on the perception of the situatedness attribute. The hypothesis was not supported with results showing the information richness attribute affected the situatedness attribute negatively (γ =-.295). In the seventh hypothesis, it was expected that learners' perception of the structuredness attribute would have a negative effect on the perception of the situatedness attribute. However, this hypothesis is not supported with results showing a positive effect. (γ =.290) In the eight hypothesis, it was expected that learners' perception of the information richness attribute would have a negative effect on the perception of the complexity attribute. This hypothesis was supported (γ =-.416).

CHAPTER 6

DISCUSSION AND IMPLICATIONS

The final chapter of the study presents a summary of the major findings, discussion of the results in terms of each hypothesis, and implications for further research. The main argument throughout this chapter was to address logical interpretations of the proposed model that would support causal relationships between perceived characteristics of problems and problem-solving performance. In other words, questions for asking why we found these results and, finally, how the findings are important for providing implications for the design of a problem to enhance problem-solving performance. Finally, this chapter is intended to promote researchers to pursue new research topics and directions in problem solving research.

Overall Perceptions of Problem Characteristics

Internal factors such as prior knowledge and motivation, relative to external factors such as the problem context, have been regarded as main influential variables that tend to influence successful problem-solving performance (Allaire & Marsiske, 2002; Jacobs et al., 2003; Jonassen, 2000; Rohlfing, Rehm, & Goecke, 2003; Smith, 1991; Taylor & Dionne, 2000). Although existing studies have addressed the relationships between the internal factors and problem-solving performance specifically, few studies have contributed to examining the relationship between external factors and problem-solving performance (e.g. Gick, 1986; Jonassen, 2000, 2003b; Smith, 1991).

Especially, researchers have not investigated the impact of the problem characteristics that may affect the problem solver's representation, integration of domain knowledge, and the selection of possible solutions (Houdeshell, 2001; Jacobs et al., 2003; Jonassen, 2003b; Peffat & Gero, 1999; Voss, 1988; Voss & Post, 1988). Given the potential impacts of problem characteristics on problem-solving performance, it is important to examine how each attribute relates to each other or influences problem-solving performance directly and indirectly in the mathematical word problem solving context in which each attribute could play a significant role.

The purpose of this study was to investigate the effect of the perceived problem characteristics on successful problem-solving performance. The focus of the current study centered on four attributes of problem-solving performance: structuredness, complexity, situatedness, and information richness. In the result, those students were not very discriminating about how the problems rated on each characteristic (See Table 2). In line with the proposed causal model, the analyses showed that all attributes except for the information richness attribute accounted for unique variance in the prediction of successful problem-solving performance directly. However, the information richness attribute accounted for unique variance in the prediction of successful problem-solving performance indirectly.

The more structured problems are perceived to be by students (the degree to which the problem's initial state, goal state, possible solutions, and constraints are clearly specified), the more likely students are to solve the problems successfully. The more complex the problem is perceived to be (the degree to which the problem's initial state, goal state, possible solutions, and constraints interact each other), the less successful problem solvers are to solve the problem. The more students perceived the problems were situated (the degree to which the specific situation in which the problem takes place is related to the problem), the less likely they were to solve the problem successfully. However, the present findings showed that information richness (how much domain knowledge is necessary to solve the problem) has no direct effect on problem solving-performance (c.f., Greeno, 1978; Jonassen, 2003; Roth & McGinn, 1997).

Although the amount of variance explained in both complexity (19%) and situatedness (15%) may appear somewhat limited, the amount of variance explained by four attributes may appear high (42%), especially considering that internal factors such as prior knowledge and motivation might account for a substantial amount of the variance. Findings from all paths of the causal model except for information richness have significant implications for successful problem-solving performance. Given the result that learners' perceptions of the four attributes of a problem independently had positive or negative direct or indirect effects on successful problem-solving performance, the next sections discuss topics that contribute to a better understanding of how and why each attribute relates to others considering the hypotheses and research questions of this study.

Effects of Problem Attribute Perceptions on Problem-Solving Performance

Structuredness

One of the main factors, structuredness, is the perceived value of the structure that a problem has. Structuredness can be recognized by the degree to which the initial state, the goal state, constraints of the problem, operators and applications of concepts and rules required for problem solving are clearly perceived by problem solvers (Allaire & Marsiske, 2002; Greeno, 1978; Jonassen, 2000, 2003b; Luszcz, 1989; Sinnott, 1989). As indicated by previous studies, structuredness plays a significant role in successful problem-solving performance (Brabeck & Wood, 1990; Dabbagh, 2002; Dillon, 2000; Houdeshell, 2001; Jonassen, 2000; Voss & Post, 1988). The result of the current study supported argumentations of previous research which indicated that structuredness had an effect on problem-solving performance.

Although the limited number of empirical studies on the impact of structuredness hinders support of the finding of the study for the impact of structuredness on problem-solving performance, various interpretations for the result can be made for five reasons. First, in line with the argumentation of Voss (1988), structuredness impacted problem solving performance because a low degree of structuredness changes a problem solver's problem solving process from a routine procedure with which the problem solver is familiar to one of unexpected procedures that he or she judges and decides.

If problem solvers can perceive the existence of an initial state, a goal state, constraints, and operators clearly (i.e., a problem is perceived as highly structured), they would think of a variety of possible paths that could support them to generate solutions and achieve the goal. In other words, the structuredness attribute enables problem solvers to speculate not only what possible paths and solutions would work to reach the desired outcome, but also why these could work when the solutions were implemented. Therefore, the highly structured problem allows them to overcome the routine procedures they have adopted and consider alternative paths and solutions.

Second, a high degree of structuredness could affect problem-solving performance by supporting problem solver to search, select, and apply a finite number of concepts, rules, and principles that they knew to constrain the situation. If problem solvers perceive a problem's structuredness to be sufficient to identify all the elements of problem states and the desired goal, they can choose suitable concepts and rules that help them to solve the problem more quickly and easily (Brabeck & Wood, 1990; Voss, 1989; Voss & Post, 1988). That is, the degree to which a problem's structure is clearly specified determines the possibility of successful problem-solving performance. Therefore, the higher a problem is perceived as structured, the more the possibility to solve the problem increases.

Third, structuredness may have affected problem-solving performance by supporting the problem solver's problem representation process that enables solvers to shift from understanding the initial state to transforming the desired state of a problem. Problem representation is an essential step for successful problem solving so that it may be impossible to solve the problem without first accomplishing the step of transforming the initial state of the problem to the goal state (Brabeck & Wood, 1990; Duch, 2001; Jonassen, 1997; Polson & Jeffries, 1983; Rittle-Johnson & Alibali, 1999). If the structuredness of a problem is perceived as organized well by problem solvers, it is easier for them to extract the final goal from the initial statement of the problem. In other words, structuredness can facilitate the understanding of the problem, which helps problem solvers to make moves to the next step while solving problems.

Fourth, the finding that the structuredness attribute influenced problem-solving performance directly suggests some instructional design considerations for problems that challenges learners to engage in problem-solving performance actively. First, the structuredness attribute highlights a general principle for training learners to solve a problem that they have never encountered. Repetitive practice for finding all elements nested in the problem clearly may lead them to understand the problem as well as move to next steps for problem-solving. Mayer(1987) designed a drill and practice program for training learners to look for each of the components of a problem. He found that this program improved problem solving performance. Mayer's study implicates the possibility of program design for problem representation in relation to problem structuredness.

Finally, although the distinction between well-structured and ill-structured of problems should be viewed as a continuum rather than a discrete dichotomy, it may be necessary to pay more attention to designing a kind of ill-structured problem, which has a highly intricate structure and cannot be solved in predictive and obvious ways because many problems we meet lack one or all of the components. However, we have no specific guidelines for generating ill-structured problems and little empirical evidence of correlations between ill-structured problems and successful problem-solving performance. Hence, new research needs to provide the important link between structuredness of problems and successful problem-solving performance.

Complexity

Complexity is usually highlighted as a specific determinant of problem-solving performance (Albers, 2002; Duch, 2001; Jonassen, 1997, 2000, 2003b; Sokol & McCloskey, 1991; Wenke & Frensch, 2003; Wood, 1986). More specifically, Jonassen (2003a) elaborated the characteristics of problem complexity as determined by how many issues are involved in a problem, the degree of their association, the types of functions of each element, and the stability of each element.

It has been argued that complexity has a negative impact on successful problem-solving performance. That is, the more complex problem solvers perceived a problem, the less likely they are to solve the problem effectively (e.g. Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003). The result of the current study also showed that the complexity attribute affected problem-solving performance negatively. If problem solvers perceive that the relationships among components of the problem are complex, they tend to fail to solve the problem. Berry (1991) argued that the criteria that determine likelihood of solvers to solve complex problems successfully depend not only on the number of components nested in the problem, but also on their clearness of interconnectivity among components (Frensch & Funke, 1995b).

Several interpretations of how the complexity attribute has a negative impact on problem-solving performance can be speculated when interpreting this finding. First, the perceived complexity can hinder problem solvers' selection of one best solution because the problem having high complexity changes dynamically over time (Jonassen, 2003; Roth & McGinn, 1997). When the conditions of a problem change, problem solvers should represent the problem continuously, consider new relationships among components of the problem, and finally search for new solutions. However, in the current study, word problems that the subjects solved were those whose conditions were relatively stable over time. Therefore, the probability that learners were able to search for one best solution and solve the problems successfully was greater than they would be for dynamic problems.

Second, problem complexity is also an obstacle for problem solvers to represent the problem as well as delineate the causes and constraints of the problems (Jonassen, 2003; Voss & Post, 1988). Problem representation requires problem solvers to understand what a problem needs, that is, to extract from the problem statement what they should do to achieve the desired goal. For that purpose, problem solvers tend to decompose the problem statement and find the meaning of each component nested in the problem. However, if the relationships among components in the problem are perceived as complex (i.e., the relationship among the problem's states, possible solutions, and constraints are not clearly specified), problem solvers may not begin to decompose components and may have difficulties in inferring the association among components. Voss, Wolfe, Lawrence, & Engle (1991) compared the information processing of problems solvers in international relations. They found that the problem solvers represented complex problems in different ways that led to different kinds of solutions. Hence, the complexity attribute influenced problem-solving performance because it was associated with the problem representation process, which is an initial step of problem solving.

Third, the complexity attribute also requires problem solvers to engage in complex cognitive processes. Sokol & McCloskey (1991) conducted a study in which they provided an arithmetic calculation problem to students. The problem that looked like a simple calculation problem was actually a complex problem. The result revealed that solving a complex problem requires heavy interplay among cognitive processes. The complexity attribute places a heavy cognitive burden on problem solvers because complexity makes solvers monitor their own problem solving process, transform each state in different ways, and postulate the relationship among components in various ways (Gick, 1986; Kitchener, 1983; Roth & McGinn, 1997; Sinnott, 1989).

It is important to emphasize that the present result has important practical implications for future research. Future research could use the complexity attribute measures to examine the validity of other perceived measures of problem characteristics, especially when prior knowledge of the domain is included in the analysis. Furthermore, what cognitive processes subjects use to perceive values of complexity and what impact of cognitive processes have on problem-solving performance need to be investigated. Previous research addressed that complexity intervenes in cognitive processes during problem solving and may be correlated with the success of problem solving. However, there is little empirical evidence to indicate what cognitive processes are associated with complexity of the problem. This question could be addressed in future research with concurrent verbal protocols collected as subjects solve problems that would map cognitive processes to a constrained task analysis.

Fourth, although the results indicated that complexity had a positive impact on problem-solving performance, complexity is partly determined by the structuredness of a problem, which had a direct effect on complexity. However, the relationship between structuredness and complexity was not the same as found in many previous studies in regard to these two attributes. That is, it has indicated that structuredness has a negative impact on complexity (Jacobs et al., 2003; Jonassen, 2000, 2003). Therefore, future research should examine what the differences are between the two attributes of structuredness and complexity, built on literature reviews and further empirical investigations. The reconceptualization of problem attributes can address new relationships between the two attributes and problem-solving performance.

Situatedness

The situatedness attribute has gained increasing attention because problem-solving performance is situated in problem-solving activities and is therefore affected by the nature of the context in which problem solvers seek to accomplish a desired outcome (Gero & Kannengiesser, 2000; Jonassen, 2003b; Peffat & Gero, 1999). Situatedness is denoted as the meaningfulness of the characteristics of a problem as interpreted through a learner's prior knowledge and experience while they encounter the problem. Roth and McGinn (1997) argued that situatedness consists of interactivity between the situation and the problem, learning to achieve the goal, and focus on the goal directly. Therefore, something that is situated means that the situation interacts with other factors to enable problem solvers to learn and achieve the goal. In this study, the situatedness attribute was defined as the degree to which the specific situation in which the problem takes place is related to the problem.

Previous studies argued that situatedness is closely associated with problem-solving performance (Jonassen, 2001). However, there has been disagreement among researchers about whether situatedness has a positive or negative impact on problem-solving performance. Some researchers such as Lindblom & Ziemke (2002) claimed that the attempt to actively engage problem solvers in social and cultural environments to complete successful problem solving is led by situatedness. The underlying assumption of their hypothesis is that a situated problem makes it easier for the problem solvers to define the problem space for themselves.

On the other hand, other researchers such as Wood (1983) argued that the situated problem becomes more difficult for problem solvers to find explicit information and solutions within the context of the situation because greater situatedness makes a problem more realistic and dynamic. In addition, problem solvers have some difficulties in responding to the problem appropriately because the elements of the problem are differently important to different learners in different contexts (Jonassen, 2000, 2003a, 2003b). The finding of the study is indicated that learners' perception of situatedness has a negative effect on successful problem solving performance.

There are many reasons why may have had an influenced negative impact on problem-solving performance. First, the situational characteristics influence the problem representation because learners represent the contextual elements nested in the problem in different ways whenever they encountered different situations. That is, situatedness requires problem solvers to understand new situational problems with various knowledge perspectives (Albers, 2002; Confrey, 1991; Jonassen, 2003b; Roth & McGinn, 1997). However, the problems addressed in the study may have lack of the contextual elements because the type of the problems is abstract and may not have any clue to generate new representation.

Second, situatedness is associated with situational knowledge. While trying to discover the meaning of the problem addressed in the study, problem solvers call on what they have been taught or from their prior knowledge of the domain. However, situatedness does not require just general domain knowledge, but demands also specific knowledge about the situation (i.e. situational knowledge) to solve the problem effectively. Thus, the success of problem-solving performance is influenced by how much problem solvers have experienced in the specific situation related to the situation where they encounter the new problem.

Third, situatedness in a problem emerges from a specific situation, and therefore, in a highly situated problem, problem solvers meet a problem that is realistic and natural. Usually, these problems should be solved immediately because a decision should be made at the correct moment in conjunction with the consideration of the needs of the external environment (Zimmerman & Campillo, 2003). Situatedness triggers problem solvers to consider urgent, dynamic decision-making requirements of the situation that they have never thought about, and the needs from environment. The unclearness of the problem space due to unfamiliarity with the situation increases the possibility of failure to solve the problem.

There are some implications of situatedness for research on problem-solving performance. The specific situation should be considered when a researcher tries to follow the format of this study or select a situation for further study. As indicated earlier, problem-solving performance could be affected by the situation in which the problem is solved. Further studies dealing with other specific situations can be examined. In addition to the generalization of the study, instructional design of problems is also dependent upon the specific situations that are more or less familiar to learners. The situatedness of a problem with respect to learners' experiences should be considered when new problem is developed and given to the learners.

Second, for research, it is possible to split learners into two groups, a contextualized problem group and a decontextualized problem group, and compare the effects of situatedness on problem-solving performance between two groups. Possible research questions for this suggestion address: 1) how do the contextualized problem group and decontextualized problem group perceive the situatedness of problems differently; 2) how much does contexualization influence problem-solving performance; 3) what are differences in the structural equation model and path coefficient between two groups with the proposed model; and 4) how do we propose a new structural equation model between two groups depending on problem-solving performance. These results can lead to better understanding the expertise research as well as problem-solving research.

Information Richness

The kinds and quantities of information inherent in a problem statement, which have been neglected as one of the relevant elements of the problem, are highlighted as a basic attribute of the problem construction. The problem's state is similar to the knowledge state dealing with highly specific task domains. Perhaps what determines the problem's features is generated by the kinds and quantities of information represented in the problem (Luszcz, 1989). Therefore, the information richness attribute has been viewed as one of several predictive factors in understanding the conditions of successful problem-solving performance. Lack of necessary information may hinder problem solvers in finding rules, operators, and solutions.

In line with the current study, Quesada, Kintsch, and Gomez (2002) stressed the importance of the information richness attribute in problem solving by distinguishing the knowledge-lean problem from the knowledge-rich problem. According to their distinction, if fine-tuned knowledge is necessary to solve the problem or if problem solvers can't solve the problem with the information presented implicitly or explicitly, the problem is a knowledge-lean problem. That is, knowledge may be weak on the part of learners or information may be weak on the part of the problem presentation. So, if problem solvers have some difficulties in solving the problem without specific knowledge that is required for the problem, information richness should be considered as a main influential factor.

However, the present study did not support the hypothesis that learners' perceptions of information richness had a positive direct or indirect effect on successful problem solving performance. That is, the present findings showed that information richness of the problem has no direct effect on problem solving-performance (c.f., Greeno, 1978; Jonassen, 2003; Roth & McGinn, 1997). There may be several reason of this result. First, the clearness of problem components may be more important than the amount of information nested in the problems because the information that is necessary for problem solvers to solve the problem may not be indispensable to solve the problems effectively (Hayes, 1989). Rather, problem solvers may perceive the quality of information as a main influential factor (Allaire & Marsiske, 2002; Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003; Polson & Jeffries, 1983). Hence, successful problem-solving performance could be attributed to the quality of information, rather than the quantity of information.

Second, a possible explanation for the effect of information richness can be made by deemphasizing its role in problem-solving performance (Duch, 2001; Habertlandt, 1997). That is, information nested in the problem is not a sufficient element to explain successful problem-solving performance, but rather a potential component to help problem solvers represent the problem, generate solutions, and search their tremendous accumulated knowledge base (Andre, 1986; Arlin, 1989; Simon, 1978). The finding that information richness has an indirect effect on successful problem-solving performance can be perceived as evidence for that explanation.

However, the present study has some implications for further research. It is necessary to investigate the relationships between each of the four components of a problem and the insufficient information represented in the problem. Although the information richness attribute has no direct effect on problem-solving performance, further research needs to find which components have close relationships with the information richness attribute because a component such as an operator may be tied to information richness. Difficulties in searching operators in the problem may be attributed to insufficient information represented in the problem.

Implications for Future Research

Overall, this study has added to previous studies by (a) questioning the relationships among the perceptions of problem characteristics and (b) investigating the relationships between the perception of problem characteristics and problem-solving performance. This study specified how these attributes related to problem-solving performance and established the existence or absence of causal relationships among these variables that influenced problem-solving performance in either positive or negative ways. Casual modeling analysis revealed that all the characteristics except for information richness had positive or negative impacts on problem solving performance. In addition, perceived characteristics had positive or negative impact on each other. This study's conclusion indicated the impact of the perceived problem characteristics as one of external factors on problem-solving performance.

Although this study showed several attributes of problems are important to the design of instructional problems, there still remain several implications for future research in relation to the purpose of the study. First, in this study, only the characteristics of problems have been examined as they influence the problem-solving performance, while purposely excluding cognitive and affective factors. Therefore, a more extensive analysis would require other variables to be considered in relation to problem-solving performance. It is likely that the inclusion of other variables may alter the relationships of problem attributes examined in this study and increase the generalizability of the study.

Second, the subject domain should be considered when a researcher tries to follow the format of this study or select a domain for further study. As indicated earlier, problem-solving performance could be affected by the domain in which the problem is solved. The domain of this study was mathematical word problems. Therefore, further studies dealing with other domains such as sociology and science can be examined.

Third, further research needs to examine the relationship between actual measures of problem characteristics and problem-solving performance. Although this study showed the relationship between perceived measures of problem characteristics and problem solving performance, the investigation of direct measures of problem characteristics would be helpful for the elaboration of the causal model as well as new relationships among variables impacting on problem-solving performance. This kind of research may lead to important implications for our understanding of the problem-solving performance and the design of problems for instruction.

Fourth, little research has been conducted to examine whether and how problems are developed sufficiently so that they challenge learners to engage in problem-solving performance actively. When instructional designers develop a new problem in a problem-based learning situation or a case based study, it is necessary to analyze the characteristics of the problems because this information provides the designers with the appropriateness of the problems in the situation. In other words, the study of problem characteristics enables instructional designers to develop new problems that engage learners in real world situations. In addition, this study can support instructional designers to analyze or select a problem that has already been developed effectively. Especially, an instrument to assess problem characteristics can play a role as a set of guidelines that support instructional designers to decide whether or not specific problems are crucial for learners to solve, and how such instructional problems can be better designed.

Ultimately, the design of instructional problems can be informed by current and future empirical research on the perceived attributes of problems across domains. That research can be used to develop instructional problems and further investigate the attributes of problems that can serve as heuristics for instructional designers to construct problems that lead to greater performance and transfer by learners.

APPENDIX A- Perception of problems' characteristics measure

This is not a test. The statements here are to find out the purpose of this survey is to find out how you perceive the problems. Please rate each statement depending on the degree to which you agree with the statement.

		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1	The problems have clearly stated goals or outcomes.					
2	The problems have clearly defined criteria for successful problem solving.					
3	The problems have clearly stated constraints that prevent successful problem solving.					
4	The problems have a single correct answer.					
5	The problems have a prescribed solution process.					
6	The problems require the solver to make assumptions and then define the solution.					
7	The problems fall within a predictable domain of knowledge.					
8	The problems exhibit the relationship between concepts and rules vaguely.					
9	The solutions of the problems are complex.					
10	The problems include too many elements, creating confusion.					
11	Because the problems contain too many aspects, the coherence is unclear.					
12	Many concepts, rules, and principles are put together in the problems.					
13	The various aspects of the problems seem to have been combined at random					
14	The elements of the problems can be represented in too may ways.					

		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
15	The problems encourage the solvers to put themselves in the situation of the problem.					
16	The problems cause the solver to think about similar problems.					
17	I had a picture in my mind while I solved the problems.					
18	The problems are different from the problems shown in the textbook or in the classroom.					
19	The problems can occur anywhere and any day.					
20	The problems reflect the real context in which the solver is actively engaged.					
21	The problems can be interpreted differently according to the situation where the solver experiences it.					
22	Much information is nested in the problems, which makes it easy to engage in active problem solving.					
23	The necessary information can be extracted from the problems.					
24	Having plenty of information is helpful to solve the problems.					
25	The most important thing during solving problems is to find the right information.					
26	It is easy to distinguish important information from unnecessary information.					
27	The problems require little specialized knowledge.					
28	The problems have many cues that help the solver to move to the next steps while solving the problem.					

APPENDIX B- Problem-solving performance material

Please solve fifteen mathematical words problems. When you are done with the first page, work on the problems on the next pages.

1. A certain ball, when dropped from any height, bounces one-half the original height. If it was dropped from 80 ft and allowed to bounce freely, what was the total distance it traveled when it hit the ground for the third time?

2. A car started on a trip from city X to city Y that is 120 mi away. It ran out of gas one-quarter of the way through the last third of the trip. How many miles did it travel before running out of gas?

3. Jack weight 25 lbs less than Phil. Bill weights 40 lbs more than Jack. Frank weights 70 lbs less than Bill. Al weights 5 lbs less than Frank. Which man is heaviest?

4. If Joe's weekly income doubled he would be making $ 70.00 a week more than Joan. Joe's weekly income is $ 20.00 more than one-half of Bill's. Bill makes $ 200.00 a week. How much does Joan make?

5. A square is 3 ft long on each side. A rectangle is 2 ft long and 7 ft wide. What is the ratio of the perimeter of the square to the perimeter of the rectangle?

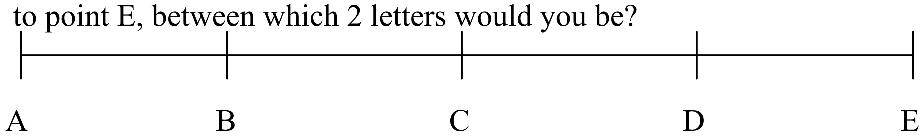
6. Mr. Smith's garden is 30 ft long and 21 ft wide and he would like to put a chain fence around it. The chain costs $ 5.00 a yard. He will support the chain by putting a metal post in each of the 4 corners and additional posts every 3ft. The posts cost $ 2.00 each. What is the total cost of the chain and posts?

7. A warped 12-inch ruler is only 11 in long. Unaware of this, Judy used the ruler to measure off 48 in of rope. What was the true length of the rope?

8. If x-8 is a positive number and x is a whole number, what is the smallest possible value of x?

9. Phil had $ 540.00 in the bank on January 1, 1971. Each year for the next several years he spent 1/3 of the money he had in the bank at the beginning of the year. How much had he spent by January 1, 1974?

10. The line below is marked off into 4 equal parts. If you start at point A and go 70% of the way to point E, between which 2 letters would you be?



11. A man wants to have a rope long enough to stretch between two poles 12 inch apart, but he has only pieces of rope each 1.5 inch long. How many of these pieces would he need to tie together to make the rope long enough to stretch between the poles?

12. This flask is being filled from a tap at a constant rate. If the depth of the water is 4 inch after 5 seconds. How deep will it be after 30 seconds?

13. A shopkeeper has two containers for apples. The first container contains 60 apples and the other 90 apples. He puts all apples into a new, bigger container. How many apples are there in that new container?

14. Sally loaned $7.00 to Betty. But Sally borrowed $15.00 from Estella and $32.00 from Joan. Moreover, Joan owes $3.00 to Estella and $7.00 to Betty. One day the girls got together at Betty’s house to straighten out their accounts. Which girl left with $18.00 more than she came with?

15. James’s weekly income is $100.00 less than triple Peter’s weekly income. Rachel’s weekly income is $20.00 more than double Peter’s weekly income. Rachel’s income is $120.00. What is James’s income?

APPENDIX C- Problem-solving performance measure

Please solve fifteen mathematical words problems. When you are done with the first page, work on the problems on the next pages.

1. A certain ball, when dropped from any height, bounces one-half the original height. If it was dropped from 80 ft and allowed to bounce freely, what was the total distance it traveled when it hit the ground for the third time?
   <u>How to solve:</u>

   <u>Answer:</u>

2. A car started on a trip from city X to city Y that is 120 mi away. It ran out of gas one-quarter of the way through the last third of the trip. How many miles did it travel before running out of gas?
   <u>How to solve:</u>

   <u>Answer:</u>

3. Jack weight 25 lbs less than Phil. Bill weights 40 lbs more than Jack. Frank weights 70 lbs less than Bill. Al weights 5 lbs less than Frank. Which man is heaviest?
   <u>How to solve:</u>

   <u>Answer:</u>

4. If Joe's weekly income doubled he would be making $ 70.00 a week more than Joan. Joe's weekly income is $ 20.00 more than one-half of Bill's. Bill makes $ 200.00 a week. How much does Joan make?
   <u>How to solve:</u>

   <u>Answer:</u>

5. A square is 3 ft long on each side. A rectangle is 2 ft long and 7 ft wide. What is the ratio of the perimeter of the square to the perimeter of the rectangle?
<u>How to solve:</u>

<u>Answer:</u>

6. Mr. Smith's garden is 30 ft long and 21 ft wide and he would like to put a chain fence around it. The chain costs $ 5.00 a yard. He will support the chain by putting a metal post in each of the 4 corners and additional posts every 3ft. The posts cost $ 2.00 each. What is the total cost of the chain and posts?
<u>How to solve:</u>

<u>Answer:</u>

7. A warped 12-inch ruler is only 11 in long. Unaware of this, Judy used the ruler to measure off 48 in of rope. What was the true length of the rope?
<u>How to solve:</u>

<u>Answer:</u>

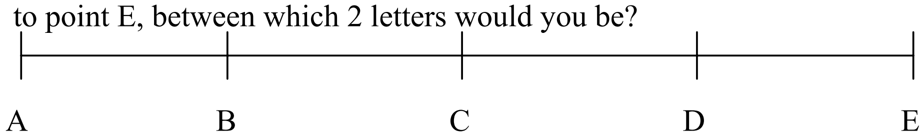
8. If x-8 is a positive number and x is a whole number, what is the smallest possible value of x?
<u>How to solve:</u>

<u>Answer:</u>

9. Phil had $ 540.00 in the bank on January 1, 1971. Each year for the next several years he spent 1/3 of the money he had in the bank at the beginning of the year. How much had he spent by January 1, 1974?
<u>How to solve:</u>

<u>Answer:</u>

10. The line below is marked off into 4 equal parts. If you start at point A and go 70% of the way to point E, between which 2 letters would you be?



<u>How to solve:</u>

<u>Answer:</u>

11. A man wants to have a rope long enough to stretch between two poles 12 inch apart, but he has only pieces of rope each 1.5 inch long. How many of these pieces would he need to tie together to make the rope long enough to stretch between the poles?
How to solve:

Answer:

12. This flask is being filled from a tap at a constant rate. If the depth of the water is 4 inch after 5 seconds. How deep will it be after 30 seconds?
How to solve:

Answer:

13. A shopkeeper has two containers for apples. The first container contains 60 apples and the other 90 apples. He puts all apples into a new, bigger container. How many apples are there in that new container?
How to solve:

Answer:

14. Sally loaned $7.00 to Betty. But Sally borrowed $15.00 from Estella and $32.00 from Joan. Moreover, Joan owes $3.00 to Estella and $7.00 to Betty. One day the girls got together at Betty's house to straighten out their accounts. Which girl left with $18.00 more than she came with?
How to solve:

Answer:

15. James's weekly income is $100.00 less than triple Peter's weekly income. Rachel's weekly income is $20.00 more than double Peter's weekly income. Rachel's income is $120.00. What is James's income?
How to solve:

Answer:

APPENDIX D- SEM data Analysis

SEM Data Analysis

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P R E L I S  2.52S

                                    BY

                        Karl G. Jeskog & Dag Sbom

The following lines were read from file C:₩이영민₩0. FSU₩A1. Dissertation₩SPSS & Lisrel₩Final data 2₩prelis.PR2:

dissertation
da ni=5
la
str1 inr1 com1 sit1 pro1
ra=b:₩data.dat
co all
ou ma=cm cm=b:₩datacov.mat


Total Sample Size =    219

Univariate Summary Statistics for Continuous Variables

Variable     Mean  St. Dev.   T-Value  Skewness  Kurtosis  Minimum Freq.  Maximum Freq.
--------     ----  --------   -------  --------  --------  ------- -----  ------- -----
    str1    3.220     0.801    59.463     0.178    -0.562    1.570     2    4.860    13
    inr1    3.223     0.668    71.362    -0.033    -0.133    1.430     1    4.860     5
    com1    2.505     0.627    59.127     0.245     0.325    1.170     1    4.710     1
    sit1    2.770     0.698    58.774    -0.070    -0.654    1.290     3    4.290     6
    pro1    3.224     0.830    57.501     0.008    -0.778    1.400     2    5.000     4

Test of Univariate Normality for Continuous Variables

             Skewness         Kurtosis      Skewness and Kurtosis

Variable Z-Score P-Value   Z-Score P-Value   Chi-Square P-Value

    str1   1.094   0.274    -2.274   0.023        6.370   0.041
    inr1  -0.203   0.839    -0.301   0.763        0.132   0.936
    com1   1.497   0.134     1.040   0.298        3.323   0.190
    sit1  -0.435   0.664    -2.858   0.004        8.359   0.015
    pro1   0.050   0.960    -3.809   0.000       14.513   0.001

Relative Multivariate Kurtosis = 0.995
```

Test of Multivariate Normality for Continuous Variables

Skewness			Kurtosis			Skewness and Kurtosis	
Value	Z-Score	P-Value	Value	Z-Score	P-Value	Chi-Square	P-Value
1.726	2.796	0.005	34.812	0.184	0.854	7.851	0.020

Histograms for Continuous Variables

str1

Frequency	Percentage	Lower Class Limit
8	3.7	1.570
19	8.7	1.899
14	6.4	2.228
44	20.1	2.557
33	15.1	2.886
23	10.5	3.215
34	15.5	3.544
16	7.3	3.873
15	6.8	4.202
13	5.9	4.531

inr1

Frequency	Percentage	Lower Class Limit
4	1.8	1.430
0	0.0	1.773
36	16.4	2.116
9	4.1	2.459
51	23.3	2.802
52	23.7	3.145
33	15.1	3.488
19	8.7	3.831
10	4.6	4.174
5	2.3	4.517

com1

Frequency	Percentage	Lower Class Limit
10	4.6	1.170
32	14.6	1.524
27	12.3	1.878
51	23.3	2.232
52	23.7	2.586
35	16.0	2.940
5	2.3	3.294
4	1.8	3.648
1	0.5	4.002
2	0.9	4.356

sit1

Frequency	Percentage	Lower Class Limit
13	5.9	1.290
16	7.3	1.590
22	10.0	1.890
25	11.4	2.190
29	13.2	2.490
41	18.7	2.790
17	7.8	3.090
41	18.7	3.390
8	3.7	3.690
7	3.2	3.990

pro1

Frequency	Percentage	Lower Class Limit	
7	3.2	1.400	□□□□□□□
15	6.8	1.760	□□□□□□□□□□□□□□□
35	16.0	2.120	□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
18	8.2	2.480	□□□□□□□□□□□□□□□□□□
35	16.0	2.840	□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
30	13.7	3.200	□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
21	9.6	3.560	□□□□□□□□□□□□□□□□□□□□□
38	17.4	3.920	□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
14	6.4	4.280	□□□□□□□□□□□□□□
6	2.7	4.640	□□□□□□

Covariance Matrix

	str1	inr1	com1	sit1	pro1
str1	0.642				
inr1	0.051	0.447			
com1	0.043	-0.114	0.393		
sit1	0.107	-0.084	0.085	0.487	
pro1	0.264	0.147	-0.119	-0.083	0.689

Means

str1	inr1	com1	sit1	pro1
3.220	3.223	2.505	2.770	3.224

Standard Deviations

str1	inr1	com1	sit1	pro1
0.801	0.668	0.627	0.698	0.830

L I S R E L 8.52

BY

Karl G. Jeskog & Dag Sbom

The following lines were read from file C:₩이영민₩0. FSU₩A1. Dissertation₩SPSS & Lisrel₩Final data 2₩simplis.SPL:

```
text example LISREL output: SC EF PC in and out
observed variables str1 inr1 com1 sit1 pro1
covariance matrix from file b:₩datacov.mat
sample size=219
latent variables str inr com sit pro
relationships
str1=1*str
inr1=1*inr
com1=1*com
sit1=1*sit
pro1=1*pro
sit=str inr
com=str inr
pro=str com sit inr
let the error variance of str1 be .1438
let the error variance of inr1 be .1280
let the error variance of com1 be .1104
let the error variance of sit1 be .1093
let the error variance of pro1 be .0954
number of decimals=3
print residuals
iterations=100
end of problem
```

Sample Size =   219

text example LISREL output: SC EF PC in and out

Covariance Matrix

	com1	sit1	pro1	str1	inr1
com1	0.393				
sit1	0.085	0.487			
pro1	-0.119	-0.083	0.689		
str1	0.043	0.107	0.264	0.642	
inr1	-0.114	-0.084	0.147	0.051	0.447

text example LISREL output: SC EF PC in and out

```
Number of Iterations =  3

LISREL Estimates (Maximum Likelihood)

        Measurement Equations


    com1 = 1.000*com, Errorvar.= 0.110, R?= 0.719

    sit1 = 1.000*sit, Errorvar.= 0.109, R?= 0.775

    pro1 = 1.000*pro, Errorvar.= 0.0954, R?= 0.861


    str1 = 1.000*str, Errorvar.= 0.144, R?= 0.776

    inr1 = 1.000*inr, Errorvar.= 0.128, R?= 0.713


        Structural Equations


     com = 0.133*str - 0.393*inr, Errorvar.= 0.231  , R?= 0.185
          (0.0664)   (0.0871)             (0.0347)
           2.002      -4.505                6.644

     sit = 0.252*str - 0.321*inr, Errorvar.= 0.321  , R?= 0.149
          (0.0744)   (0.0966)             (0.0433)
           3.394      -3.323                7.424

     pro =  - 0.379*com - 0.288*sit + 0.609*str + 0.148*inr, Errorvar.= 0.344  , R?= 0.416
             (0.128)     (0.102)     (0.0897)    (0.129)              (0.0498)
             -2.969      -2.819       6.790       1.153                 6.899


        Reduced Form Equations

     com = 0.133*str - 0.393*inr, Errorvar.= 0.231, R?= 0.185
          (0.0664)   (0.0871)
           2.002      -4.505

     sit = 0.252*str - 0.321*inr, Errorvar.= 0.321, R?= 0.149
          (0.0744)   (0.0966)
           3.394      -3.323

     pro = 0.486*str + 0.390*inr, Errorvar.= 0.404, R?= 0.315
          (0.0825)   (0.107)
           5.894       3.627


        Covariance Matrix of Independent Variables

                str        inr
           --------   --------
     str      0.498
            (0.061)
              8.102

     inr      0.052      0.318
            (0.036)    (0.043)
              1.425      7.442
```

Covariance Matrix of Latent Variables

	com	sit	pro	str	inr
com	0.283				
sit	0.049	0.377			
pro	-0.111	-0.074	0.589		
str	0.046	0.109	0.262	0.498	
inr	-0.118	-0.089	0.149	0.052	0.318

Goodness of Fit Statistics

Degrees of Freedom = 1
Minimum Fit Function Chi-Square = 2.086 (P = 0.149)
Normal Theory Weighted Least Squares Chi-Square = 2.097 (P = 0.148)
Estimated Non-centrality Parameter (NCP) = 1.097
90 Percent Confidence Interval for NCP = (0.0 ; 9.566)

Minimum Fit Function Value = 0.00957
Population Discrepancy Function Value (F0) = 0.00503
90 Percent Confidence Interval for F0 = (0.0 ; 0.0439)
Root Mean Square Error of Approximation (RMSEA) = 0.0709
90 Percent Confidence Interval for RMSEA = (0.0 ; 0.209)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.253

Expected Cross-Validation Index (ECVI) = 0.138
90 Percent Confidence Interval for ECVI = (0.133 ; 0.177)
ECVI for Saturated Model = 0.138
ECVI for Independence Model = 0.543

Chi-Square for Independence Model with 10 Degrees of Freedom = 108.447
Independence AIC = 118.447
Model AIC = 30.097
Saturated AIC = 30.000
Independence CAIC = 140.393
Model CAIC = 91.544
Saturated CAIC = 95.836

Normed Fit Index (NFI) = 0.981
Non-Normed Fit Index (NNFI) = 0.890
Parsimony Normed Fit Index (PNFI) = 0.0981
Comparative Fit Index (CFI) = 0.989
Incremental Fit Index (IFI) = 0.990
Relative Fit Index (RFI) = 0.808

Critical N (CN) = 694.452

Root Mean Square Residual (RMR) = 0.00990
Standardized RMR = 0.0221
Goodness of Fit Index (GFI) = 0.996
Adjusted Goodness of Fit Index (AGFI) = 0.943
Parsimony Goodness of Fit Index (PGFI) = 0.0664

text example LISREL output: SC EF PC in and out

Fitted Covariance Matrix

	com1	sit1	pro1	str1	inr1
com1	0.393				
sit1	0.049	0.487			
pro1	-0.111	-0.074	0.685		
str1	0.046	0.109	0.262	0.642	
inr1	-0.118	-0.089	0.149	0.052	0.446

Fitted Residuals

	com1	sit1	pro1	str1	inr1
com1	0.000				
sit1	0.035	0.000			
pro1	-0.008	-0.009	0.004		
str1	-0.003	-0.002	0.001	0.000	
inr1	0.003	0.005	-0.002	-0.001	0.001

Summary Statistics for Fitted Residuals

```
Smallest Fitted Residual =   -0.009
  Median Fitted Residual =    0.000
 Largest Fitted Residual =    0.035
```

Stemleaf Plot

```
- 0|983221000
  0|11345
  1|
  2|
  3|5
```

Standardized Residuals

	com1	sit1	pro1	str1	inr1
com1	- -				
sit1	1.448	- -			
pro1	-1.448	-1.448	1.448		
str1	-1.448	-1.448	1.448	1.448	
inr1	1.448	1.448	-1.448	-1.448	1.448

Summary Statistics for Standardized Residuals

```
Smallest Standardized Residual =   -1.448
  Median Standardized Residual =    0.000
 Largest Standardized Residual =    1.448
```

Stemleaf Plot

```
- 1|444444
- 0|00
  0|
  1|4444444
```

Time used: 0.060 Seconds

L I S R E L 8.52

BY

Karl G. Jeskog & Dag Sbom

The following lines were read from file C:₩이영민₩0. FSU₩A1. Dissertation₩SPSS & Lisrel₩Final data 2₩simplis 1.Spl:

```
text example LISREL output: SC EF PC in and out
observed variables str1 inr1 com1 sit1 pro1
covariance matrix from file b:₩datacov.mat
sample size=219
latent variables str inr com sit pro
relationships
str1=1*str
inr1=1*inr
com1=1*com
sit1=1*sit
pro1=1*pro
sit=str inr
com=str inr
pro=str com sit inr
let the error variance of str1 be .1438
let the error variance of inr1 be .1280
let the error variance of com1 be .1104
let the error variance of sit1 be .1093
let the error variance of pro1 be .0954
number of decimals=3
print residuals
iterations=100
LISREL output: SC EF PC
path diagram
end of problem
```

text example LISREL output: SC EF PC in and out

Covariance Matrix

	com1	sit1	pro1	str1	inr1
com1	0.393				
sit1	0.085	0.487			
pro1	-0.119	-0.083	0.689		
str1	0.043	0.107	0.264	0.642	
inr1	-0.114	-0.084	0.147	0.051	0.447

text example LISREL output: SC EF PC in and out

Parameter Specifications

BETA

	com	sit	pro
com	0	0	0
sit	0	0	0
pro	1	2	0

GAMMA

	str	inr
com	3	4
sit	5	6
pro	7	8

PHI

	str	inr
str	9	
inr	10	11

PSI

com	sit	pro
12	13	14

text example LISREL output: SC EF PC in and out

Number of Iterations = 3

LISREL Estimates (Maximum Likelihood)

LAMBDA-Y

	com	sit	pro
com1	1.000	- -	- -
sit1	- -	1.000	- -
pro1	- -	- -	1.000

LAMBDA-X

	str	inr
str1	1.000	- -
inr1	- -	1.000

BETA

	com	sit	pro
com	- -	- -	- -
sit	- -	- -	- -
pro	-0.379	-0.288	- -
	(0.128)	(0.102)	
	-2.969	-2.819	

GAMMA

	str	inr
com	0.133	-0.393
	(0.066)	(0.087)
	2.002	-4.505
sit	0.252	-0.321
	(0.074)	(0.097)
	3.394	-3.323
pro	0.609	0.148
	(0.090)	(0.129)
	6.790	1.153

Covariance Matrix of ETA and KSI

	com	sit	pro	str	inr
com	0.283				
sit	0.049	0.377			
pro	-0.111	-0.074	0.589		
str	0.046	0.109	0.262	0.498	
inr	-0.118	-0.089	0.149	0.052	0.318

PHI

	str	inr
str	0.498	
	(0.061)	
	8.102	
inr	0.052	0.318
	(0.036)	(0.043)
	1.425	7.442

PSI
Note: This matrix is diagonal.

com	sit	pro
0.231	0.321	0.344
(0.035)	(0.043)	(0.050)
6.644	7.424	6.899

Squared Multiple Correlations for Structural Equations

com	sit	pro
0.185	0.149	0.416

Squared Multiple Correlations for Reduced Form

com	sit	pro
0.185	0.149	0.315

Reduced Form

	str	inr
com	0.133	-0.393
	(0.066)	(0.087)
	2.002	-4.505
sit	0.252	-0.321
	(0.074)	(0.097)
	3.394	-3.323
pro	0.486	0.390
	(0.082)	(0.107)
	5.894	3.627

THETA-EPS

com1	sit1	pro1
0.110	0.109	0.095

Squared Multiple Correlations for Y - Variables

com1	sit1	pro1
0.719	0.775	0.861

THETA-DELTA

str1	inr1
0.144	0.128

Squared Multiple Correlations for X - Variables

str1	inr1
0.776	0.713

Goodness of Fit Statistics

Degrees of Freedom = 1
Minimum Fit Function Chi-Square = 2.086 (P = 0.149)
Normal Theory Weighted Least Squares Chi-Square = 2.097 (P = 0.148)
Estimated Non-centrality Parameter (NCP) = 1.097

90 Percent Confidence Interval for NCP = (0.0 ; 9.566)

Minimum Fit Function Value = 0.00957
Population Discrepancy Function Value (F0) = 0.00503
90 Percent Confidence Interval for F0 = (0.0 ; 0.0439)
Root Mean Square Error of Approximation (RMSEA) = 0.0709
90 Percent Confidence Interval for RMSEA = (0.0 ; 0.209)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.253

Expected Cross-Validation Index (ECVI) = 0.138
90 Percent Confidence Interval for ECVI = (0.133 ; 0.177)
ECVI for Saturated Model = 0.138
ECVI for Independence Model = 0.543

Chi-Square for Independence Model with 10 Degrees of Freedom = 108.447
Independence AIC = 118.447
Model AIC = 30.097
Saturated AIC = 30.000
Independence CAIC = 140.393
Model CAIC = 91.544
Saturated CAIC = 95.836

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Non-Normed Fit Index (NNFI) = 0.890
Parsimony Normed Fit Index (PNFI) = 0.0981
Comparative Fit Index (CFI) = 0.989
Incremental Fit Index (IFI) = 0.990
Relative Fit Index (RFI) = 0.808

Critical N (CN) = 694.452

Root Mean Square Residual (RMR) = 0.00990
Standardized RMR = 0.0221
Goodness of Fit Index (GFI) = 0.996
Adjusted Goodness of Fit Index (AGFI) = 0.943
Parsimony Goodness of Fit Index (PGFI) = 0.0664

text example LISREL output: SC EF PC in and out

Fitted Covariance Matrix

	com1	sit1	pro1	str1	inr1
com1	0.393				
sit1	0.049	0.487			
pro1	-0.111	-0.074	0.685		
str1	0.046	0.109	0.262	0.642	
inr1	-0.118	-0.089	0.149	0.052	0.446

Fitted Residuals

	com1	sit1	pro1	str1	inr1
com1	0.000				
sit1	0.035	0.000			
pro1	-0.008	-0.009	0.004		
str1	-0.003	-0.002	0.001	0.000	
inr1	0.003	0.005	-0.002	-0.001	0.001

Summary Statistics for Fitted Residuals

Smallest Fitted Residual = -0.009
Median Fitted Residual = 0.000
Largest Fitted Residual = 0.035

Stemleaf Plot

```
- 0|983221000
  0|11345
  1|
  2|
  3|5
```

Standardized Residuals

	com1	sit1	pro1	str1	inr1
com1	- -				
sit1	1.448	- -			
pro1	-1.448	-1.448	1.448		
str1	-1.448	-1.448	1.448	1.448	
inr1	1.448	1.448	-1.448	-1.448	1.448

Summary Statistics for Standardized Residuals

Smallest Standardized Residual = -1.448
Median Standardized Residual = 0.000
Largest Standardized Residual = 1.448

Stemleaf Plot

```
- 1|444444
- 0|00
  0|
  1|4444444
```

Covariance Matrix of Parameter Estimates

	BE 3,1	BE 3,2	GA 1,1	GA 1,2	GA 2,1	GA 2,2
BE 3,1	0.016					
BE 3,2	0.001	0.010				
GA 1,1	-0.001	0.000	0.004			
GA 1,2	0.000	0.000	-0.001	0.008		
GA 2,1	0.000	-0.001	0.000	0.000	0.006	
GA 2,2	0.000	0.000	0.000	0.000	-0.001	0.009
GA 3,1	-0.003	-0.003	0.001	0.000	0.001	0.000
GA 3,2	0.008	0.005	-0.001	0.001	-0.001	0.001
PH 1,1	0.000	0.000	0.000	0.000	0.000	0.000
PH 2,1	0.000	0.000	0.000	0.000	0.000	0.000
PH 2,2	0.000	0.000	0.000	0.001	0.000	0.001
PS 1,1	0.001	0.000	0.000	0.001	0.000	0.000
PS 2,2	0.000	0.001	0.000	0.000	0.000	0.001
PS 3,3	0.001	0.001	0.000	0.000	0.000	0.000

Covariance Matrix of Parameter Estimates

	GA 3,1	GA 3,2	PH 1,1	PH 2,1	PH 2,2	PS 1,1
GA 3,1	0.008					
GA 3,2	-0.004	0.017				
PH 1,1	-0.001	0.000	0.004			
PH 2,1	0.000	-0.001	0.000	0.001		

PH 2,2	0.000	0.000	0.000	0.000	0.002	
PS 1,1	0.000	0.000	0.000	0.000	0.000	0.001
PS 2,2	0.000	0.000	0.000	0.000	0.000	0.000
PS 3,3	-0.001	0.000	0.000	0.000	0.000	0.000

Covariance Matrix of Parameter Estimates

	PS 2,2	PS 3,3
PS 2,2	0.002	
PS 3,3	0.000	0.002

text example LISREL output: SC EF PC in and out

Correlation Matrix of Parameter Estimates

	BE 3,1	BE 3,2	GA 1,1	GA 1,2	GA 2,1	GA 2,2
BE 3,1	1.000					
BE 3,2	0.051	1.000				
GA 1,1	-0.144	-0.007	1.000			
GA 1,2	-0.018	-0.002	-0.162	1.000		
GA 2,1	-0.007	-0.148	0.051	-0.008	1.000	
GA 2,2	-0.002	-0.026	-0.008	0.050	-0.164	1.000
GA 3,1	-0.267	-0.380	0.130	-0.009	0.140	-0.003
GA 3,2	0.505	0.353	-0.086	0.074	-0.064	0.068
PH 1,1	0.008	0.014	-0.055	0.001	-0.094	0.002
PH 2,1	-0.016	-0.010	0.124	-0.041	0.092	-0.068
PH 2,2	-0.009	-0.007	-0.006	0.173	-0.004	0.127
PS 1,1	0.143	0.000	-0.075	0.177	0.000	0.000
PS 2,2	0.000	0.131	0.000	0.000	-0.109	0.133
PS 3,3	0.148	0.137	-0.021	-0.005	-0.019	-0.005

Correlation Matrix of Parameter Estimates

	GA 3,1	GA 3,2	PH 1,1	PH 2,1	PH 2,2	PS 1,1
GA 3,1	1.000					
GA 3,2	-0.358	1.000				
PH 1,1	-0.194	0.012	1.000			
PH 2,1	-0.024	-0.129	0.136	1.000		
PH 2,2	0.006	-0.050	0.009	0.137	1.000	
PS 1,1	-0.034	0.070	0.001	-0.006	0.014	1.000
PS 2,2	-0.047	0.043	0.004	-0.008	0.007	-0.003
PS 3,3	-0.252	0.069	0.023	0.009	0.001	0.010

Correlation Matrix of Parameter Estimates

	PS 2,2	PS 3,3
PS 2,2	1.000	
PS 3,3	0.009	1.000

text example LISREL output: SC EF PC in and out

Standardized Solution

LAMBDA-Y

	com	sit	pro
com1	0.532	- -	- -
sit1	- -	0.614	- -
pro1	- -	- -	0.768

LAMBDA-X

	str	inr
str1	0.706	- -
inr1	- -	0.564

BETA

	com	sit	pro
com	- -	- -	- -
sit	- -	- -	- -
pro	-0.263	-0.231	- -

GAMMA

	str	inr
com	0.176	-0.416
sit	0.290	-0.295
pro	0.560	0.109

Correlation Matrix of ETA and KSI

	com	sit	pro	str	inr
com	1.000				
sit	0.151	1.000			
pro	-0.272	-0.157	1.000		
str	0.122	0.252	0.484	1.000	
inr	-0.393	-0.257	0.344	0.130	1.000

PSI
Note: This matrix is diagonal.

com	sit	pro
0.815	0.851	0.584

Regression Matrix ETA on KSI (Standardized)

	str	inr
com	0.176	-0.416
sit	0.290	-0.295
pro	0.447	0.286

text example LISREL output: SC EF PC in and out

Completely Standardized Solution

LAMBDA-Y

	com	sit	pro
com1	0.848	- -	- -
sit1	- -	0.881	- -
pro1	- -	- -	0.928

LAMBDA-X

	str	inr
str1	0.881	- -
inr1	- -	0.844

BETA

	com	sit	pro
com	- -	- -	- -
sit	- -	- -	- -
pro	-0.263	-0.231	- -

GAMMA

	str	inr
com	0.176	-0.416
sit	0.290	-0.295
pro	0.560	0.109

Correlation Matrix of ETA and KSI

	com	sit	pro	str	inr
com	1.000				
sit	0.151	1.000			
pro	-0.272	-0.157	1.000		
str	0.122	0.252	0.484	1.000	
inr	-0.393	-0.257	0.344	0.130	1.000

PSI
Note: This matrix is diagonal.

com	sit	pro
0.815	0.851	0.584

THETA-EPS

com1	sit1	pro1
0.281	0.225	0.139

THETA-DELTA

str1	inr1
0.224	0.287

Regression Matrix ETA on KSI (Standardized)

	str	inr
com	0.176	-0.416
sit	0.290	-0.295
pro	0.447	0.286

text example LISREL output: SC EF PC in and out

Total and Indirect Effects

Total Effects of KSI on ETA

	str	inr
com	0.133	-0.393
	(0.066)	(0.087)
	2.002	-4.505
sit	0.252	-0.321
	(0.074)	(0.097)
	3.394	-3.323
pro	0.486	0.390
	(0.082)	(0.107)
	5.894	3.627

Indirect Effects of KSI on ETA

	str	inr
com	- -	- -
sit	- -	- -
pro	-0.123	0.241
	(0.049)	(0.075)
	-2.489	3.225

Total Effects of ETA on ETA

	com	sit	pro
com	- -	- -	- -
sit	- -	- -	- -
pro	-0.379	-0.288	- -
	(0.128)	(0.102)	
	-2.969	-2.819	

Largest Eigenvalue of B*B' (Stability Index) is 0.227

Total Effects of ETA on Y

	com	sit	pro
com1	1.000	- -	- -
sit1	- -	1.000	- -
pro1	-0.379	-0.288	1.000
	(0.128)	(0.102)	
	-2.969	-2.819	

Indirect Effects of ETA on Y

	com	sit	pro
com1	- -	- -	- -
sit1	- -	- -	- -
pro1	-0.379	-0.288	- -
	(0.128)	(0.102)	
	-2.969	-2.819	

Total Effects of KSI on Y

	str	inr
com1	0.133	-0.393
	(0.066)	(0.087)
	2.002	-4.505
sit1	0.252	-0.321
	(0.074)	(0.097)
	3.394	-3.323
pro1	0.486	0.390
	(0.082)	(0.107)
	5.894	3.627

text example LISREL output: SC EF PC in and out

Standardized Total and Indirect Effects

Standardized Total Effects of KSI on ETA

	str	inr
com	0.176	-0.416
sit	0.290	-0.295
pro	0.447	0.286

Standardized Indirect Effects of KSI on ETA

	str	inr
com	- -	- -
sit	- -	- -
pro	-0.113	0.177

Standardized Total Effects of ETA on ETA

	com	sit	pro
com	- -	- -	- -
sit	- -	- -	- -
pro	-0.263	-0.231	- -

Standardized Total Effects of ETA on Y

	com	sit	pro
com1	0.532	- -	- -
sit1	- -	0.614	- -
pro1	-0.202	-0.177	0.768

Completely Standardized Total Effects of ETA on Y

	com	sit	pro
com1	0.848	- -	- -
sit1	- -	0.881	- -
pro1	-0.244	-0.214	0.928

Standardized Indirect Effects of ETA on Y

	com	sit	pro
com1	- -	- -	- -
sit1	- -	- -	- -
pro1	-0.202	-0.177	- -

Completely Standardized Indirect Effects of ETA on Y

	com	sit	pro
com1	- -	- -	- -
sit1	- -	- -	- -
pro1	-0.244	-0.214	- -

Standardized Total Effects of KSI on Y

	str	inr
com1	0.094	-0.221
sit1	0.178	-0.181
pro1	0.343	0.220

Completely Standardized Total Effects of KSI on Y

	str	inr
com1	0.150	-0.353
sit1	0.255	-0.259
pro1	0.415	0.265

APPENDIX E- Human Subject Approval Letter and Informed consent form

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 3/8/2004

To:
Youngmin Lee
176 Brittain Drive# 7
Tallahassee, FL 32310

Dept.: **EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS**

From: **John Tomkowiak, Chair**

Re: **Use of Human Subjects in Research**
The Effects of Problems' Structuredness, Complexity, Situatedness, and Information Richness on Problem Solving Performance

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(b) 9 and has been approved by an accelerated review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If the project has not been completed by **3/7/2005** you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

Cc: Dr. Driscoll
HSC No. 2004.116

INFORMED CONSENT FORM

I freely and voluntarily consent to be a participant in the research project entitled "The Effect of Problems' Characteristics on Mathematical Problem Solving Performance". I must be 18 years or older to take part in this experiment. The information you provide is confidential to the extent allowed by law. It takes about 60 minutes of your time to solve some question provided.

This project is being conducted by Youngmin Lee who is a graduate student in Instructional Systems Program at the Florida State University. I understand the purpose of his project is to investigate the relationship between the characteristics of a problem and mathematical problem solving performance.

I understand that I will be asked to solve mathematical word problems. My response will be recorded on the computer in a particular data file, but no record will be kept of whose data corresponds to which data file. I will also be asked to rate the perception of problem characteristics that will be presented to me. My responses will be associated with a code number, and no records will be kept with my name on it. These records will be locked and accessible only to Youngmin Lee.

I understand that this may contact Youngmin Lee (575-1292) or Dr. Marcy Driscoll (644-8777) if I have questions about this project.

I understand there is no possibility of a minimal level of risk involved if I agree to participate in this study.

I understand that this consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am otherwise entitled to the extent allowed by law. That is, my grade in the course will not be affected if I choose to withdraw from the experiment. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction. However, I will still be obliged to fulfill my experiment participation obligation. I have read and understand this consent form.

FLORIDA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD
Approved: 03/08/04
HS No. 04.116
Void After 03/07/05

________________________ (Participant)

________________________ (Date)

APPENDIX F- Copyright Permission

COPYRIGHT PERMISSION

Dear Whimbey,

I am writing a dissertation at Florida State University entitled "Problems' Structuredness, Complexity, Situatedness, and Information Richness: The Effects of Perceptions on Problem-Solving Performance" I would like your permission to reprint in my dissertation the fifteen post-WASI test items from the following:

Whimbey, A. & Lochhead, J. (1991). Problem solving and comprehension (5th Ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Best regards,

Youngmin Lee

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

X April 19, 2004

Arthur Whimbey

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BIOGRAPHICAL SKETCH

NAME

Youngmin Lee

EDUCATION

Florida State University, Tallahassee, Florida
Major: Instructional Systems
Minor: Measurement and Statistics
Dissertation: Students' Perception of Problems' Structuredness, Complexity, Situatedness, and Information Richness and Their Effects on Problem-Solving Performance

Hanyang University, Seoul, Korea
M.A., Educational Technology, 2001
Thesis: The Effect of Web based Multi-user Object Oriented (WOO) Learning Environment on Problem Representation Learning.

Hanyang University, Seoul, Korea
B.S., Educational Technology, 1997

WORK EXPERIENCE

Tablet PC Research Team
Florida State University, Tallahassee, Florida
Research Associate, 1/2004 – 8/2004: Perform K-12 Tablet PC Implementation Project with Microsoft, HP company, and Holt Rhine Hart Publisher.

Learning Systems Institute (LSI)
Florida State University, Tallahassee, Florida
Graduate Assistant, 8/2001 – Present. Analyze knowledge career fields of U.S. Navy, Design performance support technologies for naval education and training, Redesign personnel qualification standards, Validate E-plan for naval performance improvement.

CONTACT INFORMATION

Email: edutek@dreamwiz.com or edutek74@hotmail.com