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PROMPTING STUDENTS' KNOWLEDGE INTEGRATION AND ILL-STRUCTURED PROBLEM SOLVING IN A WEB-BASED LEARNING ENVIRONMENT

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A DISSERTATION APPROVED FOR THE
DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

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DEDICATION

This dissertation is dedicated to my parents,
Lin-Feng Chen and Mei-Lan Li, for all of their support.

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God Almighty, thank you for making me so wonderfully complex! Your workmanship is marvelous - how well I know it. Every day of my life was recorded in your book. Every moment was laid out before a single day had passed. I am deeply blessed with your abundant and unfailing love. Thank you for blessing me with all the individuals who provided me the moral and intellectual support that encouraged me to complete this dissertation.

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ABSTRACT

The purpose of this study was to determine the effect of different types of question prompts on students' knowledge acquisition and ill-structured problem solving outcomes. Although there are consistent findings regarding the processes of knowledge integration in science, few studies have focused on supporting students' knowledge acquisition and problem solving in more ill-structured domains. Hence, this study explored the use of knowledge integration prompts and problem solving prompts to support students' knowledge acquisition and ill-structured problem solving, especially the processes of *problem representation*, *developing and evaluating solutions*, and *monitoring and justifying a plan of action*.

Students need to apply knowledge to important issues every day. Therefore, designing school curricula that foster integration of knowledge and everyday problem solving becomes critical. Students must develop integrated understandings of principles, prior experience, and applicable knowledge in order to be effective and efficient problem solvers.

In order to investigate how such integrated understandings can be promoted in a web-based learning environment, this research used a knowledge integration approach to teaching and learning that provided a framework for promoting the application of educational concepts to classroom problems. Educational measurement served as the educational context for the focal curriculum. The curriculum design incorporated knowledge integration prompts to help students integrate knowledge, and problem solving prompts to facilitate students' problem solving processes.

The research design and assessment protocols included two phases of the curriculum—knowledge acquisition phase and problem solving phase—and four treatments—knowledge integration condition, problem solving condition, combination of knowledge integration and problem solving condition, and control condition. The web-based environment was tested with undergraduate pre-service teachers. Pretest-posttest and ill-structured problem solving outcomes were compared between the treatments. Results indicated that knowledge integration prompts promoted better knowledge acquisition than did problem solving prompts. However, knowledge integration prompts alone were not completely sufficient for ill-structured problem solving. In fact, the combination of knowledge integration and problem solving prompts helped students not only integrate but also apply knowledge of principles and concepts to real-world problems. These results have implications for designing curricula in ill-defined domains and for instructional designers seeking to integrate and promote the application of educational principles to real-world problems.

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CHAPTER 1

INTRODUCTION

There has been substantial previous research regarding the role of students' prior knowledge in learning and instruction (e.g., Kaplan & Murphy, 1999; Thompson & Zamboanga, 2003). Bransford, Brown, and Cocking (1999) acknowledged that students often approach novel problems with existing sets of ideas, facts, and knowledge elements derived from past experiences. How students construct new knowledge upon their existing knowledge and how they apply the new knowledge to solve novel problems have recently received intensive attention by educators and researchers. The National Council of Teachers of Mathematics (2002) indicated that for students to achieve understanding, they must actively build new knowledge from prior knowledge and experience. However, knowledge building does not happen simultaneously when the new information is presented. In fact, an intentional instructional support should be provided to elicit this experience. The present work adopts a theoretical framework known as knowledge integration (Linn & His, 2000), which illustrates a process whereby students build a coherent understanding of a topic from their existing ideas and new experiences. Moreover, Linn and her colleagues (e.g., Linn & Slotta, 2000) have developed the Web-based Inquiry Science Environment (WISE) to guide students in an inquiry-oriented curriculum that ultimately promotes knowledge integration through web-based materials and technology scaffolds.

Much attention has been paid to helping students to be better problem solvers in both the classroom and the real world. The research also has started distinguishing different types of problems students encounter depending on their fields of study and the nature of the disciplines (e.g., Jonassen, 1997). Recently, awareness of the need to help students solve authentic, complex, and real-world problems has emerged in the practice and research of education (e.g., Bransford, Brown, & Cocking, 2000; Bransford & Stein, 1993; Jonassen, 1997). Hence, the goals for school science set by the National Science Educational Standards (2000) are to educate students to experience the richness and excitement of learning through inquiry and experience-based curricula and to increase their economic productivity through the use of their knowledge.

In essence, teaching problem solving explicitly is an important component of education (Simon, 1980). Problem solving is a skill that can be learned and is continuously being incorporated as a central activity in the school curriculum (Britz & Richard, 1992; Goffin & Tull, 1985). Good teachers provide the time, space, and materials necessary to promote problem solving. Unquestionably, students are expected to develop good problem solving skills through the school curriculum, apply problem solving skills when facing problems, and solve the problems they encounter.

Problem Statement

As much research indicates, students often fail to establish an adequate knowledge base because of the oversimplification of the complexity of the new knowledge and the generation of vague relationships between their prior knowledge and new knowledge (e.g., Feltovich, Spiro, Coulson, & Feltovich, 1996). The deficiencies during knowledge integration processes cause students to perceive information superficially and mindlessly (Pressley et al., 1992). Knowledge integration has been recognized as an important learning component that elicits the awareness and capacity for monitoring, active reflecting, evaluating, and modifying one’s own knowledge (e.g., Lin

& Hsi, 2000). These capabilities are also described as metacognitive processes (e.g., Lin, 2000). However, studies in knowledge integration have mostly been explored and implemented in science contexts (e.g., Davis & Linn, 2000); such science contexts often involve well-structured problems as compared to social science where more ill-structured problems exist. As a result of the dearth of investigations on knowledge integration in social science, further research is necessary to shed light on its effectiveness and efficiency with ill-structured problem solving.

In addition, research on problem solving recognizes that students often fail to apply knowledge learned in one context to another context (e.g., Bransford, Sherwood, & Sturdevant, 1987; Gick & Holyoak, 1980). In contrast to well-structured problems, ill-structured problems often possess vague initial statements, ambiguous operators, and unclear goals, which require the students to employ multiple rules, concepts, and principles to reach solution(s) (Jonassen, 1997; Kitchener, 1983). Studies have successfully helped students solve ill-structured problems; for example, providing explicit prompts or hints helped the students apply their knowledge to novel problems and achieve sound and accurate understanding of subject matter in ill-structured domains (e.g., Ge & Land, 2003). Even though more and more scholars call for research on ill-structured problems, given the nature of ill-structured problems in research, creation and assessment of such problems sometimes are unrealistic to achieve. There have been few empirical ill-structured problem solving studies. Most stay at the conceptual level and need further refinement and investigation to provide insight into this type of problem solving.

Purpose of the Study

This dissertation explores techniques that facilitate students' knowledge acquisition and ill-structured problem solving outcomes, specifically focusing on scaffolding techniques for knowledge integration and ill-structured problem solving.

Scaffolding Knowledge Integration

This study investigated the use of knowledge integration prompts to promote knowledge acquisition. It built on the findings of the Computer as Learning Partner (CLP) project, and Linn's *scaffolded knowledge integration framework* (SKI) for education (Linn, 1992, 1995; Linn & Hsi, 2000). The SKI framework was proposed to guide successful teaching practices including the adoption of technological tools for learning. The SKI framework identifies four key features: (a) setting appropriate goals for learners, (b) making expert thinking visible to learners, (c) creating a supportive social environment in the classroom, and (d) preparing students for lifelong learning. The second feature, making expert thinking visible to learners, is central to this study of knowledge integration in ill-structured domains. One important characteristic of expertise is the possession of extensive integrated content knowledge actively accessible to achieve knowledge acquisition (Bransford et al., 2000). Therefore, this study proposes that making the knowledge integration processes explicit during the students' learning results in knowledge acquisition and also facilitates ill-structured problem solving outcomes.

Scaffolding Ill-Structured Problem Solving

One important characteristic of expertise is the ability to notice relevant and often subtle features of a problem. It has been posited that students need to be scaffolded during the problem solving processes (e.g., King, 1991a). Question prompts, one of the most used scaffolding strategies, have been found to promote students' metacognitive thinking and guide them to more effective decision making processes (e.g., Lin, 2001; Saye & Brush, 2002). The present study proposed the use of problem solving prompts to facilitate students' ill-structured problem solving, although it acknowledged such prompts may only serve as checklists instead of schema activations that lead to knowledge acquisition.

Justification

Current understanding of knowledge integration is derived from substantial research, extensive classroom observation, and reflection upon a broad range of related research programs (Bransford et al., 2000; Brown & Campione, 1994; CTGV, 1997; Scardamalia & Bereiter, 1992). However, the relevant studies on knowledge integration have been lacking the context of social science, where most problems are ill-structured (Voss, Greene, Post, & Penner, 1983). Thus, whether knowledge integration contributes to ill-structured problem solving outcomes is unknown. The present investigation draws attention to claim that prompting students' knowledge integration through question prompts will have an impact on students' knowledge acquisition and problem solving outcomes on ill-structured tasks.

Research Questions

Question 1. Does the use of knowledge integration prompts have an effect on students' knowledge acquisition and problem solving outcomes in ill-structured tasks?

Question 2. Does the use of problem solving prompts have an effect on students' knowledge acquisition and problem solving outcomes in ill-structured tasks?

Question 3. Does the use of knowledge integration prompts combined with problem solving prompts have an effect on students' knowledge acquisition and problem solving outcomes in ill-structured tasks?

Question 4. How does the use of different types of prompts influence students' development of conceptual understanding?

Question 5. How does the use of different types of prompts influence students' ill-structured problem solving?

Research Hypotheses

The research questions stated above have enough basis in the literature to generate definite hypotheses. The following research hypotheses are generated on the basis of the research questions and the findings of previous research on knowledge integration and problem solving scaffolds:

Hypothesis 1: Students receiving both knowledge integration and problem solving prompts will demonstrate better knowledge acquisition than will students receiving only knowledge integration prompts, only problem solving prompts, or neither scaffolding technique.

Hypothesis 2: Students receiving both knowledge integration and problem solving prompts will demonstrate better problem solving outcomes in ill-structured tasks than will students receiving only knowledge integration prompts, only problem solving prompts, or neither scaffolding technique.

The remainder of this dissertation is divided into the following chapters: Chapter 2 will discuss the literature regarding knowledge acquisition, knowledge integration, problem solving, scaffolding theory, and question prompts. Chapter 3 will describe the design and procedure for this study. Chapter 4 will detail the results of this study, and Chapter 5 will discuss conclusions and implications for future research.

CHAPTER 2

REVIEW OF LITERATURE

This section first reviews cognitive learning theory on knowledge acquisition and describes the extent of knowledge acquisition manifested through knowledge integration. Second, the two problem types, namely, well-structured and ill-structured problems, and the processes people use in solving these problems are explored and the necessary components for solving ill-structured problems are reviewed. Third, various uses of prompts as instructional scaffolds, specifically in knowledge acquisition and ill-structured problem solving, are presented. Last, the importance of knowledge integration and problem solving prompts in ill-structured problem solving is discussed.

Theoretical Basis

The goal of education is twofold: (a) to teach students necessary knowledge and skills, and (b) to help them develop the skills to solve problems on their own. Often, when students have learned something, the learning does not necessarily improve performance. For teaching to be effective, there must be transference of declarative knowledge (knowing) into procedural knowledge (skill), or strategic knowledge (Alexander & Judy, 1988). The process of knowledge acquisition is discussed in detail in Anderson's (1982) adaptive control of thought (ACT) theory.

Knowledge Acquisition

The central element of Anderson's ACT theory is the distinction between declarative and procedural knowledge. Declarative knowledge is knowledge that is factual in nature, and is reportable. Anderson (1982) uses a data and computer program metaphor to describe how declarative knowledge is like a database of knowledge that can be accessed, recalled, and reported. Procedural knowledge is knowledge about how to accomplish tasks. It cannot be directly reported, but can only be inferred from the way an individual performs a task. As Anderson (1982) points out, in the first step of knowledge acquisition learners only have declarative knowledge about the task they are learning. This knowledge may take the form of facts about the domain, as well as about general or specific procedures. However, knowledge of these task procedures on their own cannot constitute procedural knowledge. Procedural knowledge is only developed when learners actually apply the knowledge and compile it through practice. This second step of knowledge acquisition, acquiring procedural knowledge, entails composition and proceduralization. Composition collapses a sequence of productions into a single production that has the same effect as the sequence. Proceduralization builds versions of productions that no longer require the domain-specific declarative information to be retrieved into working memory. When an individual encounters a problem, he or she will search and retrieve from memory similar problems encountered in the past. The individual then attempts to solve the problem by analogy to past examples. Therefore, the more similar the problem is to the available knowledge, the more automatization will be involved in solving the problem (Anderson, 1982).

When declarative knowledge is developed into procedural knowledge, it is further refined in the third stage of knowledge acquisition, tuning. The tuning process has three phases: generalization, discrimination, and strengthening. Generalization is the process of expanding or replacing known facts in a production with new information to broaden the production's scope of applicability. Discrimination is the result of narrowing the selection of production rules. Strengthening is the process through which competing productions are weighted based upon feedback as to their applicability. In the tuning stage of knowledge acquisition, a production gets slowly promoted over time as it proves correct, although it will be quickly deselected if it proves incorrect (Anderson, 1982). In sum, Anderson's ACT theory of cognitive skills has contributed to our understanding of how people acquire and add to complex bodies of knowledge and has explained how knowledge affects understanding. However, the theory has little to say about how learners make use of such knowledge in a particular domain or across domains. Alexander and Judy (1988) refer to the body of knowledge individuals possess relative to a particular field of study as domain knowledge. Domain knowledge includes an individual's existing conceptual knowledge related to a specific area (Alexander, 1992).

A number of studies have shown that the most salient feature distinguishing experts from novices is domain knowledge. For example, Chiesi, Spilich, and Voss (1979) conducted a study examining how domain knowledge influenced the acquisition of topic-related information. They measured students' domain knowledge with a 40-question baseball test. Then subjects were divided into two groups based on their hypothesized level of domain knowledge: high or low baseball domain knowledge. The findings indicated that acquisition of knowledge could be predicted based on level of domain knowledge. Individuals with high domain knowledge apparently have more concepts and relations to draw on, and are able to integrate more new information onto an existing structure than individuals with low domain knowledge (Chiesi et al., 1979).

The amount of knowledge experts possess is large, but their knowledge is also organized in such a way that makes that knowledge more accessible, functional, and efficient. In a study using *Star Wars* as a method to study knowledge representation, Means and Voss (1985) found that the representation of experts was quantitatively and qualitatively superior to that of novices. A large amount of domain knowledge is not the only factor responsible for the demonstration of expert-level performance; the organization of that knowledge is also important (Means & Voss, 1985; Voss, Vesonder, & Spilich, 1980). To capture the organization of knowledge representation, Chi, Feltovich, and Glaser (1981) examined the information experts and novices used to make categorization decisions. They used a classical card-sorting technique for assessing how experts and novices classified problems. Each card contained the text and diagram for a physics problem. The study found that novices tended to sort problems on the basis of literal, surface features, but the experts tended to sort the problems on the basis of the principle(s) used to solve problems (Chi et al., 1981).

In addition, experts' knowledge is highly structured. Voss and Post (1988) analyzed experts' and novices' think-aloud protocols while they solved social science problems. According to the study, experts differed from novices by exhibiting a more refined hierarchical structure in their knowledge, which allowed them to flexibly access their domain knowledge. In the domain of math teaching, Leinhardt and Smith (1985) examined expert teachers' knowledge representations by conducting extensive protocols including interviews, card-sorting tasks, and transcriptions of videotaped lessons. Not surprisingly, expert teachers displayed rich and robust knowledge and multiple representations that helped them to develop better lessons for teaching (Leinhardt & Smith, 1985). Taken as a whole, these studies have shown that a large, organized body of domain knowledge is prerequisite to expertise.

Regardless of their domain knowledge about certain content, learners may be able to employ strategic knowledge to achieve knowledge acquisition. Strategic knowledge is a special case of procedural knowledge that directs knowledge acquisition, as well as a procedure intentionally employed to overcome some deficiency in performance or to regulate one's thinking or performance (Alexander & Judy, 1988). Voss, Blais, Means, and Greene (1986) examined how naïves and novices solved everyday economics problems such as the following: "Assume the government has decided to set limits on steel imports. What effect, if any, do you think this action would have on the price of automobiles? Why?" (p. 299). It was found that college education in economics influenced the quality of problem solutions; however, formal economic training and experience did not. The study suggests ill-defined problems like the example above allow subjects to make use of their noneconomics strategic knowledge to generate the solution(s). Therefore, the need for a greater amount of economics domain knowledge is diminished. Thus, competent strategic knowledge can compensate for impoverished domain knowledge (McCutchen, 1986; Voss et al., 1986).

The concept of expertise has been explored extensively over the past few years. However, too little attention is paid to the processes that experts engage to use or acquire knowledge in carrying out complex or realistic tasks. More attention should be devoted to higher order problem solving activities that require students to actively integrate and appropriately apply subskills and conceptual knowledge. Unfortunately, in some cases, knowledge remains bound to surface features of problems as they appear in textbooks and class presentations (Resnick, 1987). To make real differences in students' problem solving skills, we need to understand the nature of expert practice with regard to the processes of integrating knowledge, and devise methods appropriate to learning that practice. Hence, conceptualized knowledge integration is described next to emphasize its characteristics and functionality.

Knowledge Integration

Wittrock (1974) posited that learning is an active process by which students construct their own knowledge in light of their existing knowledge using a process of generation, integration, and transformation of their experiential world. Students often hold multiple conflicting views before learning new information, and create their repertoire of views without reflecting on their existing knowledge. Students' existing knowledge serves as an interpretative framework for knowledge integration because new knowledge is filtered through their existing knowledge. Students' existing knowledge consequently plays a very important role in understanding new information. Understanding also goes hand-in-hand with the construction of an integrated conceptual framework. In fact, promoting such an integrated conceptual framework that furthers understanding should be explicitly taught.

Thus, Linn and her colleagues sought to design an instructional aid that promotes a more integrated student understanding of complex science concepts and processes. The Web-based Inquiry Science Environment (WISE) is one of the curriculum projects that Linn and her colleagues created to help students develop more cohesive, coherent, and thoughtful accounts of scientific phenomena (Linn, Clark, & Slotta, 2003). WISE is guided by an instructional framework called *scaffolded knowledge integration (SKI)* that was derived from substantive and extensive research such as that on cognitive apprenticeships (Collins, Brown, & Newman, 1989). Significantly, a scaffolded knowledge integration framework requires students to reflect on their deliberately developed repertoire of models for complex phenomena, and to work toward expanding, refining, reconciling, and linking these models (Bell, 2002; Linn, 1995). In an intervention study, Davis and Linn (2000) found that students who were encouraged to monitor their learning progress and identify new connections among ideas showed greater integrated understanding of the science phenomena compared to students who only devoted their attention to the inquiry process. It was indicated that the latter students were less likely to develop a robust conceptual understanding than students who compare ideas, distinguish cases, identify the links and connections among notions, seek evidence to resolve uncertainty, and sort out valid relationships, thus improving their knowledge integration (Davis & Linn, 2000).

Additionally, the absence of an integrative framework can cause students to process knowledge mindlessly and superficially without consideration of whether that idea makes sense on its own or how it integrates with other ideas (Pressley et al., 1992). Kintsch (1988) proposed a construction-integration model to illustrate how knowledge representation is developed through reading text. A construction-integration model of text comprehension assumes that two types of representation develop when reading text. One is the *text bases* representation, a propositional representation of the text content that occurs when a reader constructs a mental representation that is based only on the material read. The second is *situation bases* representation, that is integrating and absorbing important knowledge elements in the text content into the reader's knowledge system, also known as making mental maps (Kintsch, 1986). This model suggests that a text bases representation may be less likely to promote comprehension, whereas a situation bases representation may integrate the material into existing knowledge in the continuous process of building more extensive mental representations of the world (Kintsch, 1988, 1989).

Likewise, Scardamalia and Bereiter (1992) indicate that we need to prepare for student learning as knowledge building. In a computer-based learning environment called Computer-Supported Intentional Learning Environments (CSILE), students are encouraged to clarify problem statements, develop theories, state difficulties in understanding certain issues, and summarize what they have learned; thus, students are actively building their own knowledge base (Scardamalia, Bertiter, McLean, Swallow, & Woodruff, 1989). This study found that associations developed within the context of the new material are less effective for knowledge building than those developed between the new material and one's prior understanding. Instruction should support students' knowledge becoming integrated instead of static.

As indicated, the features of the scaffolded knowledge integration instructional framework recognize students' weaknesses in critically examining their own thoughts and the evidence bearing on them in both their informal thinking about everyday topics and their thinking within formal academic studies (Linn, 1992, 2000; Linn, Bell, & Hsi, 1998). The framework has been implemented in science inquiry learning contexts, in that students are constantly asked to reflect, which helps them monitor thoughts and construct a coherent and robust conceptual understanding (Linn & Hsi, 2000).

Knowledge integration inquiry has primarily been targeted toward science education and the particular properties of that domain. Little is known about whether such integration leads to students' knowledge acquisition in other domains such as social science. Subsequently, knowledge integration's impact on acquisition and its effect on knowledge construction during problem solving in other areas of social science are not yet known. It is likely that WISE and other such scaffolded knowledge frameworks would be of assistance in contexts outside of science, but little is known as to their effectiveness. Further research on implementing this framework in social science contexts would shed light on its overall effectiveness and validity.

Despite little empirical research investigating knowledge integration in ill-structured domains, the measurement of knowledge integration has demonstrated its difficulty and complexity. In the present study, concept map was used as an assessment tool to evaluate students' knowledge integration. Concept mapping, one type of spatial learning strategy, is "a way of graphically displaying concepts and relationships between or among concepts" (West, Farmer, & Wolff, 1991). Extensive research has investigated the effectiveness of concept mapping on learning. Concept mapping has been reported to enhance students' knowledge acquisition (e.g., Hall, Dansereau, & Skaggs, 1992), reading comprehension (Chmielewski & Dansereau, 1998), and learning achievement in science (Novak & Gowin, 1984). Concept mapping provides a measure of structural knowledge (Jonassen, Reeves, Hong, Harvey, & Peters, 1997). One of the few studies that looked at concept mapping as an indication of knowledge integration was conducted by King and Rosenshine (1993). They analyzed fifth-grade students' concept maps to assess their knowledge integration. However, their study failed to determine students' knowledge integration using concept mapping because they assumed students could develop concept maps without prior training. The researchers suggested that adequate training and practice on concept mapping is vital if concept mapping is to be used as a tool to examine knowledge integration. The present study investigation explores the existing literature regarding knowledge integration, and challenges the limitations of examining such an ill-structured knowledge construct by providing participants with training on concept mapping.

Knowledge Integration as the Gateway to Knowledge Acquisition

Anderson's ACT theory portrays the way knowledge is represented and processed. Both declarative and procedural knowledge play important functions in knowledge acquisition. Declarative knowledge is fundamental while procedural knowledge involves discovering and using a schema or schemata to assimilate text information and to comprehend what is read. Thus, comprehension and learning can be enhanced when students can access their own relevant schemata while reading. Existing schemata can be modified and new schemata can be constructed by the processes of accretion, tuning, and restructuring (Rumelhart & Norman, 1978). Long-term memory is assumed to have relatively permanent storage, with unlimited capacity for information.

However, for information to be stored in long-term memory, the information needs to be meaningful. The more meaning-making and elaboration, the better the information is organized and connected with existing knowledge, which enhances the ability to remember and use that knowledge. Anderson (1983) suggests that good instruction should activate schemata to make them readily available in students' working memory by making connections between what has been learned and the new information. This can be done by the use of external cognitive mechanisms such as self-questioning to encourage the activation of relevant schemata.

Hence, when an individual encounters an external stimulus, the associative network related to that stimulus within long-term memory is activated, which in turn, calls for cognitive and metacognitive activities. When such activation occurs, individuals have at their disposal the mental representations of many related concepts, links, and nodes from which to process the stimuli and take appropriate action. As a result, knowledge acquisition is achieved when students take action in the processes of knowledge integration. Knowledge integration explains how information is organized as a network-like representation consisting of nodes, which correspond to concepts, and links representing the relations between the concepts. As a learning strategy that can activate students' existing schemata and develop more robust knowledge bases, integrating knowledge results in knowledge acquisition.

Problem Solving and Problem Solving Tasks

One of the primary tenets of educational institutions from elementary to graduate and professional schools is to teach cognitive skills. Most educators agree that problem solving is one of the most important cognitive skills among intelligent human activities. Gagne (1980) stated that "the central point of education is to teach people to think, to use their rational power, and to become better problem solvers" (p.85). In essence, teaching problem solving explicitly is an important component of our education (Simon, 1980). Problem solving is a skill that can be learned and is continuously being incorporated as a central activity in the school curriculum (Britz & Richard, 1992; Goffin & Tull, 1985). Good teachers provide the time, space, and materials necessary to promote problem solving. Unquestionably, students are expected to develop good problem solving skills through the school curriculum, apply problem solving skills when facing problems, and solve the problems they encounter.

Problem Types (Well- and Ill-Structured Problems)

Opportunities for solving problems occur every day in our lives (Lesgold, 1988). Understanding the nature of the problem is important, as it will determine what kind of strategies that we should use to solve the problem. In general, all problems have three basic characteristics: (a) a given state, (b) a path constraint, and (c) a goal state (e.g., Chi & Glaser, 1985; Gick & Holyoak, 1979; Wood, 1983). The process of solving a problem starts at any given state, passes only along paths that satisfy the path constraints, and ends at any goal state. While most of the problems are considered as having all three distinct characteristics, some researchers argue that problems can be extremely diverse depending on their substance, structure, and dynamicity (Greeno, 1978, 1980; Jonassen, 2002, 2004). Thus, a learner may find only one, or all of these characteristics existing in a problem he or she is facing.

As for the problems themselves, researchers have identified two different types of problems: well-structured and ill-structured problems (e.g., Jonassen, 1997; Voss, Wolfe, Lawrence, & Eagle, 1991). The next section details these two problem types in regard to their problem characteristics and their solving processes.

Well-Structured Problem Solving

The majority of the problems students encounter in educational settings are well-structured problems, like those at the end of textbook chapters. These problems entail a relatively small number of rules, concepts, and principles for solution (Jonassen, 2000), and require a single correct, convergent answer to reach a satisfactory final solution (Simon, 1978). A well-structured problem such as a *transformative problem* consists of a well-defined initial state, a known goal state, and a constrained set of logical operator(s) and parameters (Greeno, 1978).

Most well-structured problem solving models are linear, relatively rigid, and limited in scope for they are unable to account for multiple outcomes, processes, and contexts. The most widely known, the General Problem Solver (Newell & Simon, 1972), specifies a set of powerful and general problem solving techniques including understanding and search processes that can be applied to a wide range of problems. Another well-accepted problem solving model is IDEAL by Bransford and Stein (1984), which describes problem solving as a process involving several phases: *Identify* potential problems, *Define* and represent the problem, *Explore* possible strategies, *Act* on those strategies, and *Look* back and evaluate the effect of those activities.

Gick (1986) formulated a simplified schematic diagram of the problem solving process, which includes representing problems, searching for solutions, and implementing solutions. When presented with a well-structured problem, individuals develop a problem representation from which a certain schema for that particular problem may be activated. An activated schema is a cluster of knowledge related to a problem type (Greeno, 1978). In this case, the problem-solver must identify elements and patterns in the problem and connect them to existing knowledge so that an integrated problem representation can be formed. The process of intentionally linking the problem to existing knowledge produces recognition of appropriate solution procedures for that particular problem type. As a result, little searching for a solution procedure is needed. If problem-solvers have experience with a given problem, they are able to match appropriate procedures to the solution. On the other hand, if the schema is not activated, problem-solvers have to rely on general problem solving strategies, such as means-ends analysis and decomposition, to search for a solution for the problem.

Overall, the well-structured problem solving models are descriptively very useful, but are limited because they tend to treat problem solving as either linear or cyclical in an effort to articulate a generalizable problem solving process. Jonassen (2000) states that "problem solving is not a uniform activity" (p. 65) because problem solving varies in content and context. Therefore, it is important that we also understand problems that are less well-structured.

Ill-Structured Problem Solving

In contrast to well-structured problems commonly encountered in educational settings, ill-structured problems are the kinds of problems that students face routinely in everyday life (Jonassen, 1997). Ill-structured problems have vague and less-defined goals and unstated constraint information (e.g., Chi & Glaser, 1985; Simon, 1978; Voss, 1988). These problems have no right or wrong concepts, rules, and principles for arriving at the solution (Wood, 1983) and possess multiple solutions or may not have any definite solution at all (Kitchener, 1983).

Many researchers have conducted studies to describe ill-structured problem solving. Voss and his associates (1983) conducted a study on international political science problems using the think-aloud protocol approach to understand ill-structured problem solving processes. The researchers presented three major steps, including: (a) problem representation, (b) problem solution, and (c) evaluation. Problem representation is central to the solving processes in that solvers examine the features and relations presented in the problem, isolate cause(s) of the problem and its constraints, and decompose or convert the problem. After the representation is established the solutions are presumed. Then the solvers must evaluate solutions to explore their implications for the problem (Voss et al., 1983).

Sinnott (1989) performed an in-depth analysis of respondents' solving processes in ill-structured problems also using the think-aloud protocol approach. She emphasized that the essence of a problem must be selected, then the goal(s), and finally a solution must be generated and selected among many possible solutions. As a result of the large number of goals that may be generated in ill-structured problems, Sinnott (1989) contended that the solvers must have a mechanism for selection of the best goal or solution.

In sum, ill-structured problem solving involves processes for constructing the problem space, processes for choosing and generating solutions, and a variety of memory, monitoring, and non-cognitive strategies for supporting problem solving (Sinnott, 1989). Ge and Land (2004) synthesized past studies and created a model for ill-structured problem solving, including four processes: (a) representing problem(s), (b) generating and selecting solutions, (c) making justifications, and (d) monitoring and evaluating goals and solutions. Unlike well-structured problems, ill-structured problems seldom have clear problem statements. The first step of solving an ill-structured problem is to recognize the existence of a problem. After the solvers determine a problem exists, they construct a problem representation containing all of the possible causes of the problem, as well as its possible constraints. The problem representation phase is extremely important because it determines the solution process (Voss & Post, 1988). In constructing a problem representation, problem-solvers search elements that pertain to a problem statement, and then select and evaluate critical elements that fit in the context of the problem. This could be considered similar to the schemata retrieval described in well-structured problem solving. After selecting elements, solvers generate solutions that alleviate the cause of the problem. Since ill-structured problems have divergent and alternative solutions, solvers must develop a justification for supporting the rationale of their selections of solution(s). Meanwhile, solvers also must continuously monitor and evaluate the implementation of their solution(s) in order to see how they perform (Voss & Post, 1988).

Components for Solving Ill-Structured Problems

The primary predictor of successful ill-structured problem solving is domain knowledge (e.g., Voss & Post, 1988; Voss et al., 1991). How much solvers know about a domain is important to understanding the problem and generating solutions. However, ill-structured problems cannot be solved by simply finding the information and following a constrained set of rules. In fact, that domain knowledge must be well-integrated in order to support ill-structured problem solving. Such "integratedness" is also described as structural knowledge. Structural knowledge is the knowledge of integrating domain knowledge into useful procedural knowledge for solving domain problems (Jonassen, Beissner, & Yacci, 1993). In a study conducted in the Soviet Union, Voss and his associates (1983) found that the domain knowledge possessed by novices seemed to consist of *bits and pieces* of information that were not integrated, and, ultimately, impaired their problem solving processes. A series of additional investigations on expert and novice problem solving also indicated that experts are better problem-solvers because their representations acquire more integrated domain knowledge of the problem that then helps them to construct a meaningful internal representation that can be manipulated (Chi & Bassock, 1991; Chi et al., 1981). In brief, domain knowledge is not enough to solve ill-structured problems; it must be integrated as structural knowledge to enable problem representation and solve ill-structured problems.

In addition to representational and selection complexities, ill-structured problems have no clear solution and demand that problem-solvers consider alternative goals as well as handle competing goals. This requires problem-solvers to control and monitor the selection and execution of a solution process. In other words, they have to use metacognitive skills such as self-awareness of cognitive knowledge and self-regulation of cognitive processes and strategies during problem solving (Brown, 1987). King (1991b) examined the effectiveness of self-questioning as a metacognitive strategy on students' reading comprehension. She found that self-questioning promotes internal dialogue for systematically analyzing problem information and regulating execution of cognitive strategies (King, 1991b). Likewise, Delclos and Harrington (1991) found that students who monitored their own problem solving processes tended to use more metacognitive strategies for completing the task.

In sum, successful problem-solvers use self-questioning and monitoring to gain access to guide execution of strategies, and regulate use of strategies and problem solving performance (Lin, 2001). Although well-structured and ill-structured problems share certain degrees of similarities, ill-structured problems often acquire solvers to go beyond what is represented in the problem statement and consider alternations using skills that are more metacognitive.

Instructional Scaffoldings

The National Council for the Social Studies has stated: "A central theme of reform in social sciences education for the past few years has focused on higher-order thinking within contexts that would foster civic responsibility in all students in the K-12 educational system" (as cited in Osana, Tucker, & Bennett, 2003, p. 358). Higher-order thinking has been addressed using scaffolds as instructional procedures to provide temporary support for students' initial learning before they reach intended goals (Palinscar, 1986; Rosenshine & Meister, 1992; Rosenshine, Meister, & Chapman, 1996). The notion of scaffolding is derived from "zone of proximal development" theory, that is, "the distinction between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). To put theory into practice in the study of reciprocal teaching as a scaffolded instructional tool to foster reading comprehension, researchers have taught strategies designed to guide and promote comprehension, and encouraged students to participate at whatever level possible. Students respond very well to reciprocal teaching intervention, gradually perform more and more like the adult model, and become better able to take ownership in their learning (Palinscar & Brown, 1984).

One of the most often used instructional scaffolds, question prompts, has been examined in different contexts. Next, the research and findings on the use of question prompts to enhance students' knowledge acquisition and problem solving are reviewed.

Scaffolding Knowledge Acquisition Using Knowledge Integration Prompts

Several research interventions have attempted to promote students' knowledge acquisition through prompting. Prompts are typically provided to students while they are engaged in a learning activity. For example: prompting students to self-explain what it "meant to them" while reading a passage of text so that important features of the text can be highlighted to promote greater understanding (e.g., Chi, deLeeuw, Chiu, & LaVancher, 1994). King and Rosenshine (1993) presented prompt cards to fifth-grade students while they were learning a science unit on tide pools. Prompt cards covered comparison and contrast, strength and weakness, and cause and effect types of questions such as "explain why...", "how does…affect...", "how are... and...similar and different", and "what is a new example of…". The study found that these prompts effectively taught students to construct deeper understandings of the domain (King & Rosenshine, 1993). King (1994) also found that students who received prompts were more likely to engage in complex levels of knowledge construction and their knowledge structures were more integrated. Similarly, Coleman (1998) used prompts to elicit students' explanations while they constructed knowledge maps and solved problems. Question prompts were found to lead students to construct deeper and more integrated understandings of scientific concepts (Coleman, 1998). Likewise, Hmelo and Day (1999) examined the effectiveness of prompts on medical students in a simulation-based computer environment. Students' notebooks, summaries, and responses were collected and analyzed. The study indicates that prompts help students pin down specifically where and what they did not understand (Hmelo & Day, 1999).

Lin and Lehman (1999) developed a computer-simulation program that was intended to assist students in designing biology experiments. The question prompts were used in the program to guide students' explanations and justifications. Sample prompts included: "How do you plan on going about the design?", "Why did you set up this particular experiment?", and "What would you do differently if you designed this experiment all over again?". These prompts led students to monitor their own repertoire of thoughts and construct new understanding (Lin & Lehman, 1999). Davis and Linn's (2000) study provides another example of using question prompts to construct new understanding. In that study, a web-based environment called knowledge integration environment (KIE) was used for students to collect and categorize pieces of evidence such as facts and notes in a reflective manner. The system used self-monitoring prompts to help students think carefully about their own activities, and encouraged planning and reflection. Sample prompts were: "In thinking about doing our design, we need to…"; "To do a good job on our letter, we need to…"; and "In thinking about how these ideas all fit together, we are confused about…". Students' integration was assessed through interviews, pretests and posttests, as well as the repertoire of models of science topics students developed. The study found that question prompts helped students expand their repertoire of ideas, make sense of each new, individual idea, reflect on how the new ideas integrate into their current knowledge, and thus, successfully promote knowledge integration (Davis & Linn, 2000; Linn, 2000; Linn & Hsi, 2000).

The literature reviewed above describes the benefits of prompts that explicitly call for knowledge integration. However, these prompts have been used in well-structured domains. As a result, little is known about whether or not such prompts facilitate students' knowledge integration in ill-structured domains.

The current research names the prompts which occur during text reading and before problem solving, and which are intended to promote students' knowledge acquisition as *knowledge integration prompts*. These knowledge integration prompts help students connect and refine a repertoire of their knowledge as well as emphasize making students' thinking visible and, at the same time, making the problem solving strategies explicit while students are building coherent conceptual understanding. The details on the impact of knowledge integration prompts on ill-structured problem solving are discussed later; the following section turns to the aspect of promoting ill-structured problem solving. Specifically, we must address the use of scaffolding in terms of students' problem solving outcomes in ill-structured problems.

Scaffolding Problem Solving Using Problem Solving Prompts

King (1991a) used prompts, namely, strategic prompts, to scaffold students' problem solving. She found that these prompts engaged students in the management and monitoring of their own problem solving processes. Thus, question prompts induce students to perform metacognitive processing in problem solving and guide students to employ more effective decision making processes (King, 1991a; Lin, 2001; Saye & Brush, 2002). Osman and Hannafin (1994) found that question prompts navigated students through math problem solving; however, students did not show much change in conceptual knowledge. Their study suggests that students' conceptual knowledge needs to be extended and modified externally and consciously by question prompts (Osman & Hannafin, 1994). Similarly, Davis and Linn (2000) used activity prompts that asked students to justify their own projects that directed students' attention to each aspect of their project; however, such activity prompts were found less successful in promoting knowledge integration and impaired the development of knowledge acquisition.

The studies reviewed above refer to prompts given during problem solving. These prompts focus students' attention on each step of problem solving, and encourage them to stop and think without providing instruction regarding what to think about. The current research refers to these types of prompts as *problem solving prompts*. In contrast to knowledge integration prompts, problem solving prompts attempt to focus students' attention on the processes of problem solving and the completion of tasks. Thus, problem solving prompts have the potential to promote knowledge integration to some extent, and to facilitate problem solving.

While benefits of using question prompts as instructional scaffolding have been found, question prompts have some limitations. Greene and Land's (2000) study sought to illuminate the use of scaffolding types among college students while they worked on web projects in an educational computing course. Question prompts were used to prompt students' engagement and to support their metacognition through the use of computers in a technology-rich learning environment. The findings of the study indicate that students failed to engage the questions using deep conceptual processing. The failure may have been caused by students' misconceptions and lack of integration of the information into their learning practices (Greene & Land, 2000). Considering findings from the research, the effect of different types of question prompts on promoting different learning outcomes warrants further investigation since it is likely that there are some interactive effects.

Knowledge Integration and Problem Solving Prompts in Ill-Structured Problem Solving

In line with contemporary constructivist theories, students in all content areas are required to be actively involved in the construction of knowledge (Brown & Campione, 1986; Duffy & Jonassen, 1992; Resnick, 1987). Knowledge acquisition research reiterates that effective learning involves rehearsal and practice, which implies that learners are engaged in a process of transforming their knowledge (Anderson, 1982; Resnick, 1987). When transforming knowledge, it is critical that students make inferences, elaborate on new information by adding details, and generate relationships among the new ideas and between the new material and information already in memory (e.g., Brown, Bransford, Ferrara, & Campione, 1983; Pressley et al., 1992; Wittrock, 1990).

Merely presenting information generally will not cause students to develop accurate and integrative knowledge that fosters understanding of pragmatic principle(s) and dynamic stances towards new knowledge. In fact, intentional instructional supports should be made to elicit such knowledge building processes (e.g., (Scardamalia & Bereiter, 1994; Scardamalia et al., 1989). Students need to be prompted to think about new material in such a way that they transform the material, thus constructing new knowledge. Question prompts as instructional supports have been found to effectively promote students' knowledge integration. For instance, the studies of King and Rosenshine (1993), King (1994), and Davis and Linn (2000) used prompts to engage students in knowledge integration that furthered their knowledge acquisition.

Similarly, merely asking students to solve problems without providing necessary instructional supports appears to decrease the possibility of accomplishing the problem solving process. Thus, the current research examines problem solving prompts that effectively guide students' attention to the steps in problem solving to encourage students to think about the steps in solving the problem. However, not all students are able to respond to such prompts without more guidance or hints about what to think about. The following review examines the roles of two distinct prompt types, knowledge integration and problem solving prompts in ill-structured problem solving.

Problem Representation

Gick (1986) indicates problem representation in problem solving is schema driven, in that solvers attempt to find and select critical information from memory, drawing on extremely large amounts of information. In constructing problem representations, experts retrieve the already constructed schema rather than activating externally presented complex information in working memory. In contrast, for novice students, such a process might create cognitive overload (Marcus, Cooper, & Sweller, 1996). To reduce such an effect, researchers suggest that supportive scaffoldings needs to be provided before students start working on the learning tasks (Zhang & Norman, 1994). This helps construct a cognitive schema in long-term memory that can subsequently be activated in working memory during task performance (van Merrienboer, Kirschner, & Kester, 2003). In this fashion, knowledge integration prompts serve as an external mechanism that engages students and helps them to recognize their own deficiencies, modify their existing knowledge, and reconstruct meaningful knowledge patterns, which in turn, enhances the development of cognitive schema. Such cognitive schema will be a breakthrough for students when they generate problem representation in ill-structured problems. On the other hand, problem solving prompts require students to integrate the disparate sources of information mentally. Mental integration may impose a heavy, extraneous cognitive load, and negatively affect the problem representation.

Solution and Justification Processes

If the appropriate schema activation is absent, students proceed to the second step, developing solutions, using search strategies (Gick, 1986). Search strategies involve the comparison of problem states to the goal state. In the stage of developing solutions for ill-structured problems, knowledge integration prompts play an important role in activating prior knowledge and mapping the problem onto the existing schema through integration (Davis & Linn, 2000). With integrated knowledge as the base, students are allowed to choose the best solution path and guide retrieval of appropriate procedures. Additional search strategies also can be applied in the solution process. Problem solving prompts can direct students' attention to some important information or specific features of the problem(s) to arrive at the solution(s) (e.g., Lin, 2000). However, such a technique may not guarantee the accurate solution to the problem, and also may cause cognitive overload since students may need to search for the solution while figuring out the information presented.

The ability to construct arguments is an important characteristic for successful ill-structured problem solving. Knowledge integration prompts emphasize the expansion of students' repertoires of ideas, and justify the links among ideas. Experience in knowledge integration also explicitly places students in the justification process. However, integrative knowledge alone may not be sufficient for students to consciously construct arguments for the selected solutions, especially in ill-structured problems where multiple representations and solutions may exist. External support is necessary to remind students to pay attention to specific processes while solving ill-structured problems. If appropriately scaffolded, problem solving prompts may be effective since they explicitly prompt students to be aware of their own decisions and actions, and direct students' attention to other possible solutions to the problem. Ge and Land (2003) found that students need to be prompted to construct arguments in order to justify their proposed solutions. Questions such as "Why do you suggest those strategies?" can be used to help students construct arguments.

Monitoring and Evaluation Processes

Monitoring and evaluation activities are essential throughout ill-structured problem solving. Following the implementation of a solution, students must monitor performance of the elements in the problem to see how they perform. Testing various solutions allows students to monitor problem solving processes and consider how the proposed solution would solve the problem. When students experience the elements of knowledge integration prompts, they have the opportunity to reflect on and monitor their own progress. This process provides students models that can be applied to problem solving tasks. Problem solving prompts also can help students stay on track and guide their attention to examine their proposed solution(s). For example, students can use such prompts as a checklist to guide their deliberate efforts, and use prompts to seek relevant information in the problem (Ge & Land, 2004; Ge, Chen, & Davis, 2005).

Summary

Bransford et al. (2000) indicated that, in contrast to novices, experts across domains have extensive content knowledge integrated to achieve knowledge acquisition. Experts also are more sensitive to meaningful patterns of information and possess schemata that guide their problem solving processes (e.g., Chi, Glaser, & Farr, 1988). Extensive empirical evidence indicates that question prompts are effective in promoting students' knowledge integration in science, mathematics, reading comprehension, and writing (e.g., Davis & Linn, 2000; King, 1991a, 1991b, 1994; King & Rosenshine, 1993). However, most of these prompts have been studied using well-structured contexts. Given the success of using prompts to support students' learning in science, math, reading, and writing, it is foreseeable that using prompts should support students' learning in other domains, such as social science.

The current study furthers the research on scaffolding techniques that target students' knowledge integration, and hypothesizes knowledge integration prompts will have an impact on students' knowledge acquisition and problem solving outcomes on ill-structured tasks. The concept of knowledge integration has been examined and implemented in the domain of science, and found to greatly influence students' knowledge acquisition (Davis & Linn, 2000). Knowledge integration prompts support students' schemata activation that may promote students' learning in other domains and apply to problem solving tasks. The present study also examines the utility and effectiveness of problem solving prompts for improving students' knowledge acquisition and ill-structured problem solving. Compared to knowledge integration prompts, problem solving prompts tend to guide students' attention to the steps in problem solving and the completion of the tasks. Such prompts have potential to facilitate students' knowledge acquisition during ill-structured problem solving.

In conclusion, the current research provides a new theoretical integration that expands the empirical literature in problem solving, allowing researchers to better understand the process of using or acquiring knowledge in carrying out complex or realistic tasks. The study also addresses a current theoretical gap in the literature in attempting to answer whether prompts targeted at students' knowledge integration will have an impact on students' knowledge acquisition, and whether the knowledge acquired during acquisition learning will hinder or facilitate subsequent ill-structured problem solving.

CHAPTER 3

METHODOLOGY

This study investigated: (a) the effects of knowledge integration and problem solving prompts as an approach to enhance students' knowledge acquisition, and (b) the effects of knowledge integration and problem solving prompts on students' problem solving outcomes on ill-structured tasks.

The following sections restate the research questions and hypotheses, discuss subjects, design, materials, instruments, data collection procedures, and data analysis for the experimental study and the multiple case study.

Research Questions

Question 1. Does the use of knowledge integration prompts have an effect on students' knowledge acquisition and problem solving outcomes in ill-structured tasks?

Question 2. Does the use of problem solving prompts have an effect on students' knowledge acquisition and problem solving outcomes in ill-structured tasks?

Question 3. Does the use of knowledge integration prompts combined with problem solving prompts have an effect on students' knowledge acquisition and problem solving outcomes in ill-structured tasks?

Question 4. How does the use of different types of prompts influence students' development of conceptual understanding?

Question 5. How does the use of different types of prompts influence students' ill-structured problem solving?

Hypotheses

Hypothesis 1: Students receiving both knowledge integration and problem solving prompts will demonstrate better knowledge acquisition than will students receiving only knowledge integration prompts, only problem solving prompts, or neither scaffolding technique.

Hypothesis 2: Students receiving both knowledge integration and problem solving prompts will demonstrate better problem solving outcomes in ill-structured tasks than will students receiving only knowledge integration prompts, only problem solving prompts, or neither scaffolding technique.

Subjects

The subjects for this study were 87 undergraduate students enrolled in undergraduate educational psychology courses at a public university in the south central United States. The researcher selected these particular students for several reasons. First, educational psychology is a domain in which the researcher possesses adequate knowledge to support student learning. Second, the researcher assumes that most of the students have received some informal and formal instruction throughout their coursework, but they have little or no experience applying what they have learned to solve real-world and complex problems in regard to teaching and instruction. Finally, because the experimental topic, assessment, is directly relevant to the students, their performance for this study will accurately reflect their knowledge and interest more than other topics (such as political science), which might be seen merely as an irrelevant experimental tasks.

Of the 87 subjects, 65 (75%) were female, 53 (61%) were aged 18-21, 76 (90%) were Caucasian, 48 (55%) were juniors, and 34 (39%) were elementary education majors (see Tables 3.1 and 3.2).

Table 3.1
Demographic Data

Sex	N (%)	Age	N (%)	Ethnicity	N (%)	Year	N (%)
Female	65 (74.7%)	18-21	53 (60.9%)	Africa American	4 (4.7%)	Sophomore	2 (2.3%)
Male	22 (25.3%)	22-25	24 (27.6%)	Hispanic	2 (2.4%)	Junior	48 (55.2%)
		26-29	5 (5.7%)	Asian/Pacific Islander	3 (3.2%)	Senior	28 (32.2%)
		30 and above	5 (5.7%)	Caucasian	76 (89.4%)	Graduate	9 (10.3%)

Table 3.2
Subject Major Areas

	Majors							
	Early Childhood	Elementary Education	Social Sciences	Special Education	Science Education	English Education	Foreign Language	Music Education
N (%)	20(23%)	34(39.1%)	12(13.8%)	7(8.0%)	5(5.7%)	5(5.7%)	3(3.4%)	1(1.1%)

In addition, within this group of subjects, 53 (61%) reported that they had taken at least 2 educational psychology courses, 71 (82%) had taken either 0 or 1 instructional technology course, and 58 (67%) had not taken any educational measurement classes of any kind before. Concerning their understanding of reliability and validity in educational measurement, 70 (90%) reported that they knew a very limited amount of information about these topics. With regard to subjects' self-perceptions of using computers to do things related to their classes and using the Internet/World Wide Web to find information and resources, most students reported that they possess adequate abilities to use both computer and Internet to accomplish the tasks. During the data collection process, three subjects were disqualified because they could not attend the second session of the study.

At the end of the data collection process, there were 84 subjects; the results reported in Chapter 4 are based on the data of these 84 subjects.

Research Design

The research questions and attendant methodologies are summarized in Table 3.3. The researcher used both quantitative and qualitative methods to examine the effects of prompt types, specifically knowledge integration and problem solving prompts, on students' knowledge acquisition and problem solving outcomes in ill-structured tasks.

A quantitative methodology measured students' knowledge acquisition and their problem solving outcomes in ill-structured tasks through an experimental study. The purpose of the quantitative study was to examine the relationship between the instructional interventions/prompt types and students' knowledge acquisition/problem solving outcomes in ill-structured tasks. However, the quantitative study was not able to provide a rich and comprehensive picture in terms of how the experimental materials influenced students' thinking during problem solving processes.

A qualitative methodology was followed to help clarify quantitative statistical relationships and served to triangulate the numeric findings. This type of mixed method study was described by Creswell (2002) as an explanatory design.

Table 3.3
Research Questions, Study Design, Instruments, Data Sources and Analysis

Research question	Study design	Task/Material/Instrument	Data source	Data analysis
1. Does the use of knowledge integration prompts increase students' knowledge acquisition and ill-structured problem solving?	Experimental	Instruction phase 1&2 Ill-structured problem-solving tasks	Pre-experimental test Post-experimental test	Repeated measure ANOVA
2. Does the use of problem solving prompts increase students' knowledge acquisition and ill-structured problem solving?	Experimental	Instruction phase 1&2 Ill-structured problem-solving tasks	Pre-experimental test Post-experimental test	Repeated measure ANOVA
3. Does the use of knowledge integration prompts combined with problem solving prompts increase students' knowledge acquisition and ill-structured problem solving?	Experimental	Instruction phase 1&2 Ill-structured problem solving tasks	Pre-experimental test Post-experimental test	Repeated measure ANOVA
4. How does the use of different types of question prompts influence students' development of conceptual understanding?	Talk-aloud protocol Interview	Instruction phase 1&2 Ill-structured problem solving tasks	Talk-aloud protocol transcriptions Interview transcriptions	Case study
5. How does the use of different types of question prompts influence students' ill-structured problem solving?	Talk-aloud protocol Interview	Instruction phase 1&2 Ill-structured problem solving tasks	Talk-aloud protocol transcriptions Interview transcriptions	Case study

Experimental Study

Design

The experimental study was conducted to answer the first three research questions regarding the effects of prompt types on students' knowledge acquisition and problem solving outcomes on ill-structured tasks. A randomized pretest-posttest control group design was employed. The independent variables of this study were: (a) knowledge integration prompts appearing in the knowledge acquisition phase, and (b) problem solving prompts appearing in the problem solving phase. The dependent variables were: (a) knowledge acquisition and (b) problem solving outcomes on ill-structured tasks. Students' knowledge acquisition was measured based on the results of their topic knowledge tests. Students' problem solving outcomes on ill-structured tasks were assessed based on their performance in the following areas: (a) problem representation, (b) solution and justification processes, and (c) monitoring and evaluation processes.

As illustrated in Table 3.4, in the experimental study participants were randomly assigned to work in four different conditions. As suggested by Creswell (2002), approximately 20 participants in each condition in an experimental study is sufficient per condition. All conditions included collection of: (a) demographic information, (b) pre-experimental and post-experimental tests, (c) instructional passages about educational measurement, and (d) ill-structured problems. Conditions varied depending on what kind of treatments the participants received in the knowledge acquisition and problem solving phases. Specifically:

Knowledge integration (KI) condition. Students received knowledge integration prompts (see Appendix C) during the knowledge acquisition phase (KAP) and no problem solving prompts during the problem solving phase (PSP).

Problem solving (PS) condition. Students received no knowledge integration prompts during the knowledge acquisition phase (KAP) but received problem solving prompts (see Appendix B) during the problem solving phase (PSP).

Knowledge integration and problem solving (KP) condition. Students received knowledge integration prompts during the knowledge acquisition phase (KAP) and also received problem solving prompts during the problem solving phase (PSP).

Control condition. Students received neither knowledge integration prompts during the knowledge acquisition phase (KAP) nor problem solving prompts during the problem solving phase (PSP).

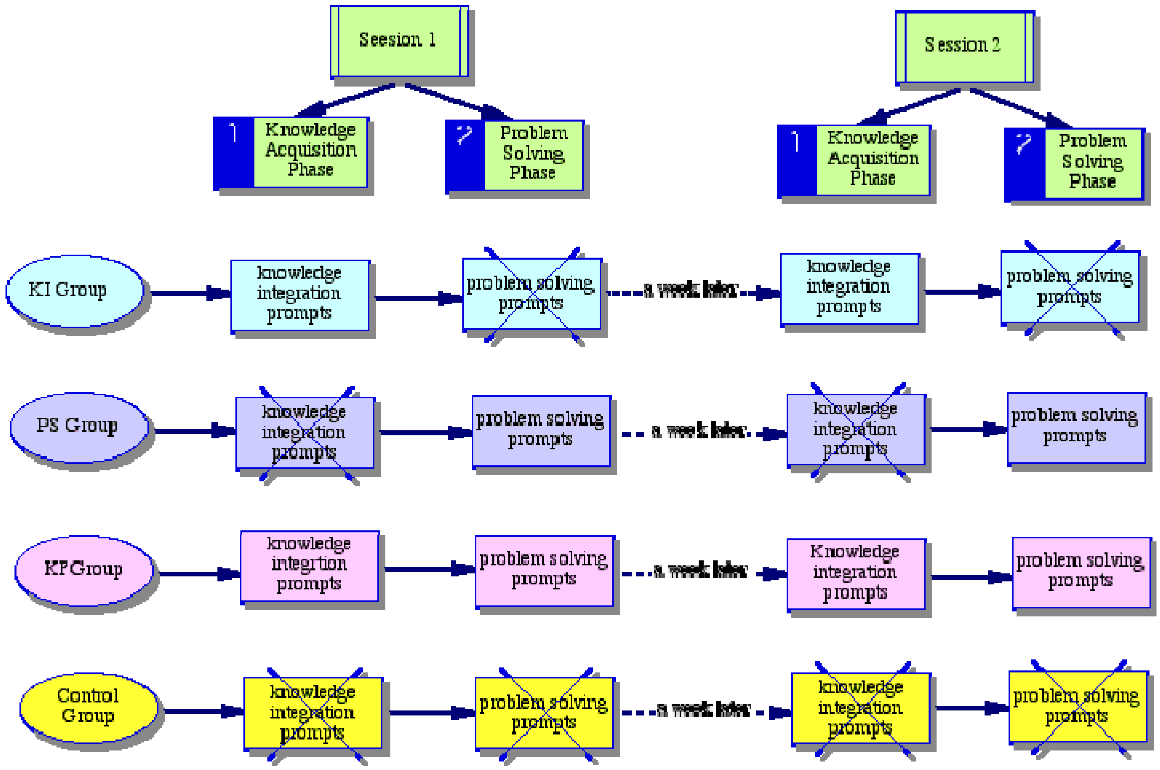

Figure 3.1 Research Design

Materials/Instruments

The materials for the experimental study included instructional passages about educational measurement, knowledge integration prompts, problem solving prompts, and ill-structured problem solving tasks.

The instructional passages about educational measurement were adapted from the textbook used by undergraduates in their introductory educational psychology class. The knowledge integration prompts (see Appendix C) were adapted from King (1994) and Linn (1995) studies, which addressed critiquing, interpreting, and explaining. These questions were designed to facilitate students' understanding of domain knowledge and to promote knowledge integration that developed a robust conceptual understanding. On the other hand, problem solving prompts (see Appendix C) were generated to be parallel with the ill-structured problem solving processes proposed by Ge and Land (2003, 2004). Problem solving prompts were designed to navigate students through problem solving processes and helped with the completion of the task.

The ill-structured problem solving tasks were developed by the researcher. These ill-structured problem solving tasks were complex, authentic problems related to the topic of educational measurement. To obtain content and construct validity, instructors who teach the undergraduate or graduate educational measurement courses and experts in ill-structured problem solving (e.g., educational researchers) were asked to help validate the problems. These experts agreed that the problems represented the major attributes of ill-structured problems as defined in the literature (e.g., Jonassen, 1997; Sinnott, 1989; Voss & Post, 1988).

The three-part instrument was given to the participants during the experimental study. The first part consisted of the pre- and post-experimental tests. The second part was the problem solving test. The third part included surveys concerning participants' perceptions of text passages, prompts, ease of use/navigation of the web-based instruction, and interests.

The pre- and post-experimental tests assessed students' knowledge in educational measurement (See Appendix C). The researcher developed the items, which were parallel to the instructional passages provided for participants. The items were evaluated by instructors from the measurement and evaluation courses to ensure that the items were adequately and appropriately represented. The items included terminology tests (7 items), identification tests (6 items), comprehension tests (6 items), and application tests (5 items). The maximum score for the topic knowledge test was 24. A split half internal consistency for the experimental test was .75. A pilot study with 19 items was prepared prior to the main study. Its split-half internal consistency produced a .65 reliability coefficient. Therefore, five additional items were added for the main study (for details on the pilot study, see Appendix B).

The second part of the instrument evaluated students' problem solving outcomes. To assess students' problem solving outcomes, a scoring coding scheme was developed. Students' problem solving outcomes were scored numerically based on their performances on: (a) problem representation, (b) developing and justifying solution(s), and (c) monitoring and evaluating a plan of action. These coding schemes were chosen because they serve as indicators for the processes in solving ill-structured tasks (Ge & Land, 2004). Each criterion was then broken into sub-criteria to allow more in-depth investigation. The rubric was validated by instructors from the educational psychology department and experts in ill-structured problem solving research. Participants' problem solving reports first were graded by two raters separately using the rubric developed by the researcher. Before grading, two raters reached a conceptual consensus regarding how to interpret the scoring rubrics through discussion and examples. Any discrepancies of assigned values were discussed among raters. Consequently, a high consensus was reached. A pilot study was conducted prior to the main study, and the results revealed that the scoring rubric has a reliability coefficient of .87.

In addition to the experimental tests and the problem solving test, the third part of instrument was a survey on subjects' perceptions of text passages, prompts, ease of use/navigation of the web-based instruction, interests, and cognitive overload (see Appendix D). Questions on text passages were as following: "This instructional text required concentration," "Reading the instructional text required complex thinking," and so forth. Questions on the prompts were as following: "These questions required me to hold too much in my head at one time," "I did not have to think very hard when answering these questions," and so forth. Questions on ease of use/navigation were as following: "In terms of navigation, this lesson was simple to use," "In terms of navigation, this lesson could have been easier to use," and so forth. Questions on their interests were as follows: "My level of interest remained steady throughout this module," "Reliability and validity are interesting topics," and so forth. The students were to answer these questions on a scale of 1 to 6; 1 was strongly disagree, and 6 was strongly agree. For the measurement of cognitive overload, the researcher adapted the instrument used by Paas and van Merrienboer (1993, 1994). A scale of 1 to 9 was used; 1 was very, very low mental effort, and 9 was very, very high mental effort.

Procedures

Four versions of web-based learning environments were created. A database was developed so that participants' responses could be saved and retrieved later. Data were collected twice during two sessions, one week apart. Participants chose their own participation times from a variety of times offered. At the first session, participants were randomly assigned a code used throughout the study to login to the website. The website started with an overall description of the site, the purpose, and the tasks for the participants. Then the participants were asked to fill out a demographic questionnaire and a set of pre-experimental tests. After the pre-experimental tests, the system instructed participants to read a set of instructional passages about educational measurement. Only the participants in the KI and KP conditions received a series of knowledge integration prompts while they were reading the passages. The system required participants to respond to each of the questions by typing their responses in the online text boxes provided. Their completed responses to the knowledge integration prompts were saved for retrieval by the participants and researcher at a later time.

After reading the passages, participants proceeded to the problem solving phase. In the problem solving phase, an ill-structured problem was given, and students were asked to solve the problem. To complete the ill-structured problem, students were required to apply their educational measurement knowledge and skills to analyze the problem and suggest the solution(s). A list of problem solving prompts was provided for the participants in the PS and KP condition only. These participants were required to respond to each of the questions in the online text boxes. These responses were saved in the database so the participants could retrieve, copy, and paste when they worked on their final solution reports. After completing the first session, the subjects were thanked for their participation and reminded of the second session of this study.

One week later, subjects returned to participate in the second session. In the second session, the system instructed students to read the instructional passages shown, solve another ill-structured problem, answer questions if there were any, and complete a post-experimental test.

The Comparative Multiple-Case Study

In addition to the experimental study, a comparative, multiple-case study was conducted to answer the research questions regarding how different prompt types support students' knowledge acquisition and problem solving outcomes on ill-structured tasks.

According to Yin (1994), a rich, theoretical framework is important to the multi-case study design. The multiple cases should enable the researcher to either predict similar results or produce contrasting results for the purpose of theoretical replication (Yin, 1994). Three participants from each of the four conditions were selected from the experimental study to provide additional evidence based on a selective sampling technique suggested by Strauss and Corbin (1998). This selective sampling technique allows opportunities for interpretive analyses across different conditions.

Materials/Instruments

Two techniques were applied to study the selected samples: a) talk-aloud protocol during concept mapping construction, and b) interviews. The talk-aloud was used to capture evidence of students' knowledge integration, thinking, reasoning, and conceptual understanding in different treatment conditions, with or without prompts. This protocol provided in-depth information on how different prompts influence students' knowledge integration and promote better conceptual understanding.

Procedures

Prior to the experimental treatment, participants were asked to create a concept map of the issues important to educational measurement; they engaged in the talk-aloud protocol while doing so. Then the researcher asked participants to explain their concept maps and prompted them with questions designed to further indicate the level of knowledge that participants possessed about educational measurement.

In the second session of the study, the same participants who participated in the concept map construction in the first session were asked to construct another concept map on the topic of educational measurement after they completed the second module of web-based instruction. As in the first session, they performed a talk-aloud protocol. Immediately upon completion of the talk-aloud protocol concept map construction, they were interviewed. The interviews were semi-structured in that students were asked to reflect upon their experiences in and impressions of this study. Both talk-alouds and interviews were audio tape-recorded. Students' additional participation was compensated with ten dollar gift certificates.

Data Analysis

Quantitative data were analyzed first, followed by qualitative data. Quantitative data sources consisted of students' pre- and post-experimental tests, and problem solving outcomes on ill-structured tasks. The data sources for the qualitative data included the audiotaped talk-alouds and interviews. The following describes the data analysis procedures and methods for both quantitative and qualitative data.

Quantitative Data Analysis

The data were analyzed using the SPSS statistical software package. To determine that the four conditions of the groups were initially equivalent, a one-way ANOVA was performed to compare the scores of the four groups on the pre-experimental test.

Repeated-measures analysis of variance, a procedure to examine change over time within subjects, was applied for the data analysis. Stevens (2001) suggested that if any repeated factor is present, then repeated measures ANOVA should be used. Repeated measures ANOVA was performed to determine whether there was a main effect for the treatment group, a main effect for time, or a group by time interaction for knowledge acquisition and problem solving outcomes. The independent variable was treatment group including KI, PS, KP and Control. The repeated measure was time including pre- and post-experimental tests. The treatment group was a between-subject factor. Time was a within-subject factor. The dependent variables were knowledge acquisition and problem solving outcomes.

Qualitative Data Analysis

Participants' talk-aloud protocols for concept mapping construction and interviews after the experimental condition were transcribed for data analyses. Three primary levels of data analyses were applied: (a) initial analysis and coding of multiple cases individually, (b) indexing and clustering of emerging themes, and (c) induction of meta-themes and patterns (Miles & Huberman, 1994).

In the first step, the researcher read the transcripts several times and wrote margin notes. Margin notes then were entered and indexed into a data display matrix. This matrix provided an overview of within and cross-case comparisons of students' understanding of conceptual knowledge about educational measurement by conditions (KI, PS, KP, and Control). The next level of analysis was group-related segments that led to explanations for each research question.

To validate the accuracy of the findings, triangulation and external audit were employed. The present study considered the information from both students' talk-aloud protocols and interviews, so the findings were not drawn from a single source, thus increasing both accuracy and credibility. In addition, a second researcher also coded all of the data and negotiated differences until 100 percent agreement on coding was achieved.

Summary

The study investigated the effects of knowledge integration prompts and problem solving prompts on students' knowledge acquisition and problem solving outcomes on ill-structured tasks. The study hypothesized that students in KI condition (who only received knowledge integration prompts) and KP condition (who received both knowledge integration and problem solving prompts) would experience the most significant gains on their knowledge acquisition and problem solving outcomes, compared with students in PS condition (who only received problem solving prompts), and Control condition (who received neither knowledge integration nor problem solving prompts). A repeated measures ANOVA was performed to analyze the results; talk-aloud protocols and interviews also were conducted and analyzed to provide in-depth information to support the quantitative findings.

CHAPTER 4

RESULTS

This chapter presents the results from the data analyses of the experimental study and the interpretive, multiple-case study. The results of the experimental study will be reported first, in response to research questions 1-3. Next, the findings from the comparative, multiple-case study will be summarized and discussed. The qualitative results are expected to provide in-depth insights into the findings of the experimental study and to explain issues related to research questions 4 and 5.

The Experimental Study Results

This study investigated: (a) the effects of knowledge integration and problem solving prompts as an approach to enhance students' knowledge acquisition, and (b) the effects of knowledge integration and problem solving prompts on students' problem solving outcomes on ill-structured tasks. The findings for research questions 1-3 are summarized below.

Students' Knowledge Acquisition

A repeated measures ANOVA was conducted to evaluate whether there was a main effect for the treatment group, a main effect for time, or a group by time interaction for knowledge acquisition. The independent variable was the treatment group including KI, PS, KP, and Control. The repeated measure was time including: (a) a pre-experimental test, and (b) a post-experimental test. The treatment group was a between-subject factor. Time was a within-subject factor. The dependent variable was knowledge acquisition. The Time main effect and Treatment X Time interaction effect were tested using the multivariate criterion of Wilks's lambda (Λ). The results for the ANOVA indicated a significant time effect, Wilks's lambda (Λ) = .79, F (1, 80) = 21.33, $p < .01$, $\eta^2 = .21$, observed power 1.00. The interaction between time and treatment was also found significant, Wilks's lambda (Λ) = .91, F (3, 80) = 2.78, $p = .05$, $\eta^2 = .10$, observed power .65. These results suggest that the time that students spent on the study had an effect on their performance. The researcher then conducted the MANCOVA to evaluate the relationship between the covariate and the dependent variables. Tests of within-subjects effects indicated that students' overall GPA was significant, F (1, 73) = 5.73, $p = .02$, $\eta^2 = .07$, observed power .66, as well as students' major GPA, F (1, 57) = 4.06, $p = .05$, $\eta^2 = .07$, observed power .51. In addition, the numbers of assessment classes that students took previously also was found to interact with the posttests, F (1, 79) = 4.80, $p = .03$, $\eta^2 = .06$, observed power .58. This means students' overall and major grade point average, and their prior knowledge had a great influence on the results of the post-experimental test.

Multivariate analysis of variance was employed to indicate overall differences for the treatment group effect and the dependent variables. The MANOVA results showed that the result of students' pre-experimental tests were not significant, F (3, 84) = .19, $p = .90$, $\eta^2 = .01$, observed power .09. The results of students' post-experimental tests were found to be significant, F (3, 84) = 4.34, $p = .01$, $\eta^2 = .14$, observed power .85. This means there were some statistical differences in students' post-experimental tests between groups. Table 4.1 presents the results of MANOVA, showing descriptive statistics as well as overall differences for the treatment group effect and the two dependent variables, pre- and post-experimental tests.

Table 4.1
Analysis of Variance of Pre and Post Experimental Tests by Treatment Group

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
Pretest	KI	10.6364	2.55502	22
	PS	10.1429	2.22004	21
	KP	10.4286	2.78516	21
	Control	10.6500	2.32322	20
	Total	10.4643	2.44677	84
Posttest	KI	14.2273	3.90277	22
	PS	11.8095	2.71328	21
	KP	12.3810	2.59762	21
	Control	10.9500	2.83725	20
	Total	12.3810	3.25208	84

Multivariate Tests(d)

Effect		Value	F	Hypothesis df	Error df	Sig.	Eta Squared	Observed Power(a)
Intercept	Pillai's Trace	.970	1260.691(b)	2.000	79.000	.000	.970	1.000
	Wilks' Lambda	.030	1260.691(b)	2.000	79.000	.000	.970	1.000
	Hotelling's Trace	31.916	1260.691(b)	2.000	79.000	.000	.970	1.000
	Roy's Largest Root	31.916	1260.691(b)	2.000	79.000	.000	.970	1.000
GROUP	Pillai's Trace	.147	2.116	6.000	160.000	.054	.074	.747
	Wilks' Lambda	.854	2.164(b)	6.000	158.000	.049	.076	.758
	Hotelling's Trace	.170	2.210	6.000	156.000	.045	.078	.768
	Roy's Largest Root	.163	4.353(c)	3.000	80.000	.007	.140	.854

a Computed using alpha = .05
b Exact statistic
c The statistic is an upper bound on F that yields a lower bound on the significance level.
d Design: Intercept+GROUP

Tests of Between-Subjects Effects

Dependent Variable: Pre-Experimental Test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power(a)
Corrected Model	3.538(b)	3	1.179	.191	.902	.007	.084
Intercept	9187.952	1	9187.952	1489.872	.000	.949	1.000
GROUP	3.538	3	1.179	.191	.902	.007	.084
Error	493.355	80	6.167				
Total	9695.000	84					
Corrected Total	496.893	83					

Table 4.1 *(Continued)*

Dependent Variable: Post Experimental Test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power(a)
Corrected Model	122.805(c)	3	40.935	4.337	.007	.140	.853
Intercept	12780.643	1	12780.643	1354.233	.000	.944	1.000
GROUP	122.805	3	40.935	4.337	.007	.140	.853
Error	755.004	80	9.438				
Total	13754.000	84					
Corrected Total	877.810	83					

a Computed using alpha = .05
b R Squared = .007 (Adjusted R Squared = -.030)
c R Squared = .140 (Adjusted R Squared = .108)

A post hoc comparison procedure was further performed for each dependent variable to identify significantly where the difference resides. Table 4.2 presents the results of post hoc comparison procedures. No significance between groups was found in the students' pre-experimental tests. In the post-experimental tests, group 1 (KI) had the highest mean scores, and was found significantly different from group 4 (Control).

Table 4.2
The Results of Post Hoc Comparison Procedures

Dependent Variable	(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pre test	KI	PS	.4935	.75761	.915	-1.4944	2.4814
		KP	.2078	.75761	.993	-1.7801	2.1957
		Control	-.0136	.76724	1.000	-2.0268	1.9995
	PS	KI	-.4935	.75761	.915	-2.4814	1.4944
		KP	-.2857	.76637	.982	-2.2966	1.7251
		Control	-.5071	.77589	.914	-2.5430	1.5287
	KP	KI	-.2078	.75761	.993	-2.1957	1.7801
		PS	.2857	.76637	.982	-1.7251	2.2966
		Control	-.2214	.77589	.992	-2.2573	1.8144
	Control	KI	.0136	.76724	1.000	-1.9995	2.0268
		PS	.5071	.77589	.914	-1.5287	2.5430
		KP	.2214	.77589	.992	-1.8144	2.2573
Post test	KI	PS	2.4177	.93722	.056	-.0414	4.8769
		KP	1.8463	.93722	.208	-.6128	4.3055
		Control	3.2773	.94913	.005(*)	.7869	5.7677
	PS	KI	-2.4177	.93722	.056	-4.8769	.0414
		KP	-.5714	.94806	.931	-3.0590	1.9161
		Control	.8595	.95984	.807	-1.6590	3.3780
	KP	KI	-1.8463	.93722	.208	-4.3055	.6128
		PS	.5714	.94806	.931	-1.9161	3.0590
		Control	1.4310	.95984	.448	-1.0875	3.9494
	Control	KI	-3.2773	.94913	.005(*)	-5.7677	-.7869
		PS	-.8595	.95984	.807	-3.3780	1.6590
		KP	-1.4310	.95984	.448	-3.9494	1.0875

Based on observed means.
* The mean difference is significant at the .05 level.

Students' Ill-Structured Problem Solving Outcomes

Following a repeated measure ANOVA investigating the effects of question prompts on students' knowledge acquisition, a MANOVA was employed to examine the effects of different types of question prompts and the three dependent variables of problem solving processes (i.e., problem representation, developing and justifying solutions, and monitoring and evaluating a plan of action). The MANOVA results were statistically significant, $p < .01$, $\eta^2 = .16$, observed power 1.00. This means that there were some statistically significant differences on at least one dependent variable. Further, the results of the univariate ANOVA tests revealed that there were statistically significant differences in problem representation and developing and justifying solution dependent variables. Table 4.3 is a summary of the multivariate analysis of variance on each dependent variable.

Table 4.3
Multivariate analysis of Variance of Dependent Variables by Treatment Group

Descriptive Statistics

	GROUP	Mean	Std. Deviation	N
Problem representation	KI	1.5909	.59922	22
	PS	1.0633	.49036	21
	KP	1.6190	.55061	21
	Control	1.0997	.63177	20
	Total	1.3491	.61871	84
Developing solutions	KI	1.0600	.84655	22
	PS	1.5552	.66955	21
	KP	1.7141	.48611	21
	Control	1.0165	.82011	20
	Total	1.3370	.77031	84
Monitoring and evaluating a plan of action	KI	1.9545	1.29935	22
	PS	1.7143	.88842	21
	KP	1.9524	.89310	21
	Control	1.3500	.90467	20
	Total	1.7500	1.02822	84

Multivariate Tests(d)

Effect		Value	F	Hypothesis df	Error df	Sig.	Eta Squared	Observed Power(a)
Intercept	Pillai's Trace	.868	171.622(b)	3.000	78.000	.000	.868	1.000
	Wilks' Lambda	.132	171.622(b)	3.000	78.000	.000	.868	1.000
	Hotelling's Trace	6.601	171.622(b)	3.000	78.000	.000	.868	1.000
	Roy's Largest Root	6.601	171.622(b)	3.000	78.000	.000	.868	1.000
GROUP	Pillai's Trace	.448	4.686	9.000	240.000	.000	.149	.999
	Wilks' Lambda	.603	4.874	9.000	189.982	.000	.155	.994
	Hotelling's Trace	.574	4.892	9.000	230.000	.000	.161	.999
	Roy's Largest Root	.359	9.586(c)	3.000	80.000	.000	.264	.997

a Computed using alpha = .05
b Exact statistic
c The statistic is an upper bound on F that yields a lower bound on the significance level.
d Design: Intercept+GROUP

Table 4.3 *(Continued)*

Tests of Between-Subjects Effects

Dependent Variable: Problem Representation

Source	Type III Sum of Squares	*df*	Mean Square	F	Sig.	Eta Squared	Observed Power(a)
Corrected Model	5.776(b)	3	1.925	5.925	.001	.182	.947
Intercept	151.388	1	151.388	465.871	.000	.853	1.000
GROUP	5.776	3	1.925	5.925	.001	.182	.947
Error	25.997	80	.325				
Total	184.656	84					
Corrected Total	31.773	83					

Dependent Variable: Developing and Justifying Solutions

Source	Type III Sum of Squares	*df*	Mean Square	F	Sig.	Eta Squared	Observed Power(a)
Corrected Model	7.729(c)	3	2.576	4.964	.003	.157	.900
Intercept	149.866	1	149.866	288.753	.000	.783	1.000
GROUP	7.729	3	2.576	4.964	.003	.157	.900
Error	41.521	80	.519				
Total	199.402	84					
Corrected Total	49.250	83					

Dependent Variable: Monitoring and Evaluating a Plan of Action

Source	Type III Sum of Squares	*df*	Mean Square	F	Sig.	Eta Squared	Observed Power(a)
Corrected Model	5.007(d)	3	1.669	1.614	.193	.057	.409
Intercept	254.849	1	254.849	246.401	.000	.755	1.000
GROUP	5.007	3	1.669	1.614	.193	.057	.409
Error	82.743	80	1.034				
Total	345.000	84					
Corrected Total	87.750	83					

a Computed using alpha = .05
b R Squared = .182 (Adjusted R Squared = .151)
c R Squared = .157 (Adjusted R Squared = .125)
d R Squared = .057 (Adjusted R Squared = .022)

The researcher further investigated the univariate statistical results by performing post hoc comparison procedures to identify significantly where the difference resided. Table 4.4 presents the results of post hoc comparison procedures.

Table 4.4
The Results of the Post Hoc Comparison Procedures

Dependent Variable	GROUP (I)	GROUP (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Problem representation	KI	PS	.5276	.17391	.017(*)	.0713	.9839
		KP	-.0281	.17391	.998	-.4845	.4282
		Control	.4912	.17612	.033(*)	.0291	.9534
	PS	KI	-.5276	.17391	.017(*)	-.9839	-.0713
		KP	-.5557	.17592	.012(*)	-1.0173	-.0941
		Control	-.0363	.17811	.997	-.5037	.4310
	KP	KI	.0281	.17391	.998	-.4282	.4845
		PS	.5557	.17592	.012(*)	.0941	1.0173
		Control	.5194	.17811	.023(*)	.0521	.9867
	Control	KI	-.4912	.17612	.033(*)	-.9534	-.0291
		PS	.0363	.17811	.997	-.4310	.5037
		KP	-.5194	.17811	.023(*)	-.9867	-.0521
Developing solutions	KI	PS	-.4952	.21979	.118	-1.0719	.0815
		KP	-.6541	.21979	.020(*)	-1.2308	-.0774
		Control	.0435	.22258	.997	-.5405	.6275
	PS	KI	.4952	.21979	.118	-.0815	1.0719
		KP	-.1589	.22233	.891	-.7422	.4245
		Control	.5387	.22509	.087	-.0519	1.1293
	KP	KI	.6541	.21979	.020(*)	.0774	1.2308
		PS	.1589	.22233	.891	-.4245	.7422
		Control	.6976	.22509	.014(*)	.1070	1.2882
	Control	KI	-.0435	.22258	.997	-.6275	.5405
		PS	-.5387	.22509	.087	-1.1293	.0519
		KP	-.6976	.22509	.014(*)	-1.2882	-.1070
Monitoring and evaluating a plan of action	KI	PS	.2403	.31027	.866	-.5738	1.0544
		KP	.0022	.31027	1.000	-.8119	.8163
		Control	.6045	.31421	.226	-.2199	1.4290
	PS	KI	-.2403	.31027	.866	-1.0544	.5738
		KP	-.2381	.31385	.873	-1.0616	.5854
		Control	.3643	.31775	.662	-.4694	1.1980
	KP	KI	-.0022	.31027	1.000	-.8163	.8119
		PS	.2381	.31385	.873	-.5854	1.0616
		Control	.6024	.31775	.238	-.2314	1.4361
	Control	KI	-.6045	.31421	.226	-1.4290	.2199
		PS	-.3643	.31775	.662	-1.1980	.4694
		KP	-.6024	.31775	.238	-1.4361	.2314

Based on observed means.
* The mean difference is significant at the .05 level.

Problem representation. The result of post hoc comparison shows that there is a significant difference in means between KI/PS groups, KI/Control, KP/PS, and KP/Control groups. There is not a significant difference in means between Group 1 (KI) and Group 3 (KP). This indicated that students who received knowledge integration prompts significantly outperformed those who did not receive any in the problem representation phase during the problem solving task.

Developing and justifying solutions. In developing and justifying solutions phase of the problem solving task, significant differences in means were found between KP/KI groups, and KP/Control groups. The KP group did significantly better than the KI and Control groups.

Monitoring and evaluating a plan of action. As shown in Table 4.4, there were no significant differences in means between groups in monitoring and evaluating a plan of action during ill-structured problem solving.

Students' Perceptions of Text Passages, Prompts, Ease of Use/Navigation of the Web-Based Instruction, Interests, and Cognitive Overload

A one-way ANOVA was conducted to examine whether there were any differences in students' perceptions of text passages, prompts, ease of use/navigation of the web-based instruction, interests, and cognitive overload among the four conditions. The results showed significant group difference only in cognitive overload, F (3, 84) = 3.24, p =.03, η^2 = .11, observed power .73. KI had a significantly higher mean score on overload (M=6.32) than KP (M=6.24), PS (M=5.72), and Control (M=5.50).

The Comparative Multiple-Case Study Results

Twelve cases from different conditions were selected for comparative case study analyses. The following subsections give brief introductions of the cases and compare them according to conceptual representations from the concept mapping, perceptions of scaffolding strategies, and cognitive processes during the ill-structured problem solving.

Twelve cases from the four conditions were selected: 3 from KI, 3 from PS, 3 from KP, and 3 from Control. Within each group, subjects were randomly selected based on their agreement to participate in the talk-aloud activity during concept mapping construction and the follow-up interviews. These selected participants were to develop two concept maps, one in each of the two sessions. However, two participants in the PS group failed to return to the second session. Therefore, the interpretation of concept maps from the PS group is based on a single participant. Cross-case comparison analyses revealed two major themes: (a) students who received knowledge integration prompts showed dramatical knowledge acquisition and concept maps changes, and (b) the problem solving prompts had an influence on students' intentional efforts in analyzing the problems and seeking information. The treatment condition is indicated in parentheses. Pseudonyms are used to protect the identity of the participants.

Group by Group Comparisons on Knowledge Acquisition Changes

All the participants across the groups started the concept map tasks by relating to their prior knowledge and experience of educational measurement. For example, John (KI) used a black cloud as an illustration of what educational measurement is nowadays in the school. Most of the participants did not agree that the standardized test was a reliable and valid measurement of the students' abilities. However, none of the participants could incorporate reliability and validity concepts in their first concept map; even when asked to talk about the concepts, they had a hard time explaining the meanings. For example, Sam (KP) and Marie (KP) had heard of the reliability and validity concepts before, but they could not describe what they meant using their own words. Sandy (KI) and Michelle (KP) vaguely explained the meaning of the concepts but were not able to clarify the relationship between them. Most of the participants included components of educational measurement they thought were important or that they had learned by the time this study occurred. Chelsea (KI), Jonathan (PS), and Molly (Control) indicated in their maps that types of testing methods were important to the topic of educational measurement. Molly (Control) and Celine (Control) mentioned that “No Child Left Behind” and childhood illiteracy issues should be taken into consideration when it comes to educational measurement. In the first concept map, the participants had difficulty drawing maps demonstrating what they knew about educational measurement because their knowledge and experience in educational measurement was limited and could only rely on their prior knowledge and experience.

Across the groups, all participants showed different changes in their knowledge about educational measurement from the first concept map to the second. In the second concept map, participants in the KI and KP groups showed a better ability to integrate domain knowledge into useful procedural knowledge than participants in the PS and Control groups. For instance, Sandy (KI) and Michelle (KP) not only were able to provide declarative forms of knowledge, but also clarified the relationships among the concepts and incorporated them into the concept map. John (KI) and Chelsea (KI) were able to explain the relationships among the concepts and transfer them to assess different types of testing methods. Sam (KP) and Marie (KP) were able to explain what the concepts meant using their own words and relate these concepts to different testing methods. On the other hand, participants who were in the PS and Control groups were not able to correctly define the concepts and indicate their relationships with other concepts. Table 4.5 summarizes the analysis and interpretation of knowledge acquisition representations by group from concept maps and talk-aloud protocols.

Group by Group Comparisons on the Follow-up Interviews

Participants in the KI and KP groups indicated that knowledge integration prompts were helpful during the problem solving task. According to Sandy (KI), "I would not have known anything about the concepts, if I have not thought about or [been] asked to answer questions [knowledge integration prompts] before hand. And yeah, I would not have been able to answer the case study if I did not have answered [sic] these questions before." Thus, prompts helped participants engage in thinking about the concepts critically and enabled them to bridge the gap between their past knowledge and new knowledge. Most participants thought these prompts helped them to reflect on their own knowledge, but they had to exert much mental effort into answering them. Those who did not receive knowledge integration prompts indicated that they felt they had learned something, but towards the end when they were being quizzed, they could not remember anything at all.

Participants in the PS and KP groups indicated that problem solving prompts were helpful to deconstruct the problems into smaller problems. Jonathan (PS) said these questions "helped me to separate questions out and think about how the information applied to each question; instead of just throwing one big question at me, I basically pulled it out and put it together.” These prompts also allowed participants to apply what they had learned to the real classroom situation. All the participants enjoyed these questions because they helped them see how the knowledge they learned could be applied to their lives. Those who did not receive problem solving prompts thought the case study was hard since they had to rely so heavily on memorization.

Table 4.5

Analysis of Knowledge Acquisition Representations by Group from Concept Maps and Talk-aloud Protocols

Criteria	Groups	Descriptors	Examples
Concept identification	KI	Descriptive, Thorough	"Reliability means the consistency." "Validity is just the truth of it, if it accurately shows what you should know about a certain subject, but a very specific subject."
	PS	Fuzzy, Vague	"Reliability is making sure your assessment is thought out and planned and tested out, so that it checks for what you want it to, what you want to assess." "Validity is like knowing it's a valid assessment that you have, and you can try it a lot."
	KP	Descriptive, Thorough, Detailed	"…correlates with reliability is consistency, it is rated from zero to one. There are different measures of reliability. For example, test/retest. This is to check if a student still knows after a certain period time…" "For validity, it looks at how well the interpretation of the scores was used and it is measured in degrees."
	Control	Incomplete	"Reliability is like what you are actually measurements of the test rather than the validity is the test itself."
Concept connection	KI	Informative, Connected	"Reliability is more or less a consequence of validity. Reliability can be reliable even though you can be a totally useless test. Validity implies reliability. When the validity is strong, it's going to accurately test the results and, always going to show you exactly what a child can do on a certain subject."
	PS	Less connected, Incomplete	"To be reliable, you can have low validity. But you cannot have true validity without reliability."
	KP	Informative	"Reliability and validity are related. If I am a teacher, I need to make sure the test I am administering is reliable and valid. I'd look at the validity, the result as ok after I am giving this test out how consistent is it if it is given again in a couple months. If I will give them a unit test, I would see if the content related or is well with what I taught."
	Control	Incoherent, Confused	"I think reliability and validity need to be there, but reliability cannot or can exist without validity."
Concept structure	KI	Linear, Hierarchical	See Appendix F for Sample Concept Maps
	PS	Incomplete	
	KP	Elaborate	
	Control	Incomplete	

CHAPTER 5

DISCUSSION

Overview of the Findings

This study investigated the effects of web-based question prompts, namely knowledge integration and problem solving, on students' knowledge acquisition and problem solving outcomes on ill-structured tasks. Students' knowledge acquisition in educational measurement was tested before and after the study. Problem solving performance was measured according to (a) problem representation, (b) developing and justifying solutions, and (c) monitoring and evaluating a plan of action. The effects of knowledge integration and problem solving prompts were examined when they were tested separately as well as when they were combined. The findings related to research questions, from both quantitative and qualitative data sources, are summarized below, followed by a discussion of the implications for instructional design and future research.

1. Question prompts targeting students' knowledge integration had a positive effect on students' knowledge acquisition and ill-structured problem solving outcomes, specifically in problem representation and the development and justification of solutions.

First, the students in the KI condition (received knowledge integration prompts only) significantly outperformed those in the PS (received problem solving prompts only) and Control conditions (received no prompts) in the post-experimental test. Second, the students in the KP condition (received both knowledge integration and problem solving prompts) did as well as the students in the KI condition on the post-experimental test. This further validates the claim that knowledge integration prompts better assist students in understanding the concepts they have learned and increasing their knowledge acquisition outcomes. The students who did not receive knowledge integration prompts did not perform significantly better than the students who received these prompts. These findings on knowledge integration prompts support the hypothesis that knowledge integration prompts not only expand the students' repertoire of ideas in well-structured domains as shown by the study of Davis and Linn (2000), but also in ill-structured domains.

The students who received knowledge integration prompts (both KI and KP groups) performed better in problem representation and the development of solutions than those who did not receive any (PS and Control groups). This finding adds to the existing literature on how knowledge integration helps to promote ill-structured problem solving outcomes.

2. Question prompts targeting students' problem solving showed less effect on students' knowledge acquisition, but these prompts helped students develop solutions, as well as monitor and evaluate a plan of action in the ill-structured problem solving.

The study did not show that students who received problem solving prompts significantly improved their knowledge acquisition outcomes compared to those who received knowledge integration prompts, but the students with problem solving prompts were shown to perform better in developing solutions in ill-structured problems. These prompts guided students' metacognitive thinking and further directed the analysis of ill-structured problems. This finding is consistent with previous research on scaffolding students' ill-structured problem solving in a web-based learning environment (Ge, Chen, & Davis, 2006).

3. Question prompts targeting students' knowledge integration helped students to organize, self-check, reflect, and elaborate on their conceptual understanding. The prompts also made a smooth transition for students during problem solving.

The concept map talk-aloud protocols revealed in-depth explanations on the process of students' conceptual changes. The students who received knowledge integration prompts seemed to have better insight into the concepts' meanings, interrelationships, and applications. The knowledge integration prompts in this study, such as "explain why and how…", helped the students reflect upon and internalize the knowledge. Questions such as "compare differences and similarities…" helped the students to make connections between different aspects of concepts, to pay attention to the importance of each concept, and to monitor their own understanding. Hence, knowledge integration prompts seemed to enhance students' understanding of domain knowledge. From this aspect, knowledge integration prompts facilitated students' cognitive thinking.

When asked to define the concepts, students in the KI and KP groups seemed to gain more knowledge than students in the PS and Control groups. The KI and KP students who came in with no knowledge about the concepts were able to provide explanations about what the concepts meant and evaluate different testing methods using the concepts they had learned (Cases Sam & Marie). The students who came in with vague knowledge about the concepts were able to clarify the relationships among the concepts and incorporate the concepts into their maps (Cases Sandy & Michelle). Those who had already obtained good knowledge of what the concepts meant but did not apply the concepts correctly were able to see the relationship and connection of the concepts to the testing methods (John & Chelsea).

Finally, the qualitative data showed that knowledge integration prompts helped participants draw ideas together and fully cement them (John, Sandy, Chelsea, & Marie). These prompts engaged them in self-checking, monitoring, and reflecting upon their understanding of the concepts (Cases Chelsea, Sam, & Michelle). Further, these prompts gave them an ease in transforming the knowledge to solve case studies later (Cases Sandy, Chelsea, & Sam).

Likewise, from the discussion of the findings, it is evident that questions targeting the development of students' integrative knowledge can be used to scaffold students' knowledge acquisition and problem representation in ill-structured problem solving tasks. The qualitative results highlight the influence of knowledge integration prompts on focusing students' attention on integrating prior knowledge with new knowledge, self-evaluating and reflecting upon what is known and not known, and developing a coherent and robust conceptual understanding. Such prompts also ease the identification of problems in ill-structured problem solving.

Moreover, the quantitative results point to the effects of knowledge integration prompts on knowledge acquisition and problem representation in ill-structured problem solving tasks. While knowledge integration prompts supported problem representation, they did not seem to help with developing solutions, and monitoring and evaluating a plan of action. This indicates that acquiring knowledge and problem solving are two separate cognitive skills. The students may acquire adequate knowledge bases, but they are not automatically transferring that knowledge to other aspects of problem solving processes such as developing solutions and monitoring and evaluating in ill-structured problem solving. In fact, when developing solutions as well as monitoring and evaluating a plan of action, students not only need an adequate knowledge base of the subject but also to be cued and guided intentionally.

4. Question prompts targeting students' problem solving processes helped students to analyze the problems step-by-step, but did not seem to directly help with students' conceptual understanding.

The qualitative study revealed that problem solving prompts, such as "what do you believe is the primary problem…?" and "what other problem might be occurring …?", helped the students to deconstruct the problems and brainstorm the possible problems within the case study. Further, these prompts allowed the students to assess the case study step-by-step. Additionally, problem solving prompts helped the students to reflect upon and explain their own actions and decisions, with questions such as "what specific strategies do you want to suggest…, and why?" Previous literature has shown that self-explanation facilitates problem solving processes (Chi et al., 1989). This finding is also consistent with Lin and Lehman's (1999) claim that question prompts can engage students to make arguments for their decisions and thus make thinking explicit.

However, this study did not find problem solving prompts facilitated student's knowledge acquisition. For example, Jonathan came in with ambiguous and vague knowledge, and at the end of the study he expressed that he had trouble explaining the concepts using his own words without going back to the study.

Furthermore, the qualitative findings seemed to be consistent with the quantitative results, in which students in the conditions of PS and Control (who did not receive knowledge integration prompts) had significantly lower performance on knowledge acquisition than did those who received knowledge integration prompts. From the qualitative findings, students who only received problem solving prompts failed to provide a specific explanation of the concepts, such as the interrelationship among the concepts. Such prompts also failed to provide cues or to activate students' schemata. As a result, students provided superficial explanations of the concepts and did not apply concepts correctly, which suggested their vague and limited knowledge base. This finding further explains why the effects of problem solving prompts were not helpful in problem representation. Although problem solving prompts helped students to develop solution(s), such prompts alone were not sufficient for helping students in developing solutions; in fact, knowledge integration prompts must co-exist with problem solving prompts to make the latter work to their full potential.

Conclusions

This study had three primary goals: (a) to extend previous research regarding the importance of knowledge integration in scaffolding knowledge acquisition and ill-structured problem solving, particularly in a different domain (i.e., educational psychology) and in a web-based learning environment; (b) to confirm the effectiveness of procedural prompts (i.e., problem solving) in scaffolding knowledge acquisition and ill-structured problem solving; (c) to examine the interactions between different types of question prompts (KI and PS) in the process of acquiring knowledge and problem solving.

This study extends the literature on ill-structured problem solving in a social science domain. The findings suggest that with this web-based learning environment, embedded with prompts targeting knowledge integration, students developed integrated understanding of educational measurement in spite of the challenges students face learning this topic. When prompted to proceed with the knowledge integration process, students abandon single knowledge elements for multiple knowledge elements so that new or stronger connections were fostered through engagement in this web-based learning environment. By the end the students were more likely to explain their reasoning with a well-integrated answer than with a less connected answer. Another important finding is that the integrated understanding, in conjunction with the web-based embedded problem solving prompts, helped students apply educational concepts to real-world problems. Student reasoning concerning educational problems was more grounded in measurement issues. The design strategy of blending knowledge integration and problem solving settings provided explicit opportunities to connect the knowledge that was acquired to their classroom problems.

Implications for Education

Results from this research indicate that a knowledge integration approach to facilitate knowledge acquisition provides students with a richly connected set of educational ideas that can be applied to everyday, real-world problems. This has implications for the design of educational curricula. In particular, three design principles emerge from this research.

First, students can develop a richer understanding of sophisticated educational measurement when they are given opportunities to connect their perspectives on teaching to educational measurement principles. Therefore, instruction needs to elicit student ideas by asking students to express what they know about educational measurement prior to promoting the connection of concepts in educational measurement.

Second, students can develop a more connected understanding of topics from experiencing real-world problems. In this study, the web-based learning environment was designed to prompt students to integrate ideas learned prior to and during the study, and apply them to the real-world problems.

Third, prompting knowledge integration can help students move from simplistic reasoning about education measurement to complex reasoning that involves the application of education to real-world classroom environment.

Implications for the Design of Web-Based Cognitive Modeling System

Web-based learning has considerable promise in the development and facilitation of students' understanding. This study yields several implications for designing such an environment to support the development of cognitive skills and models of understanding.

First, in order to effectively support cognitive development, system is needed to facilitate intentional reflection and retention. Such mechanism will raise students' awareness to recognize the gaps and detect biases in their knowledge bases. Therefore, the web-based cognitive modeling system should structure opportunities for intentional reflection.

Second, in order to engage students in meaningful learning, the system should provide real-world problems to help students reconcile the application part of knowledge. Students often experience difficulty connecting educational theories with real-world problems; therefore, utilizing question prompts to act as a mediator for the instructor role will enable the linking system to activate students' knowledge application.

Last, but not least, it may be useful to provide feedback or features that structure opportunities for students to interact with the experts and their peers. Distance learning is characterized by the separation between instructors and the students, whether by temporal or spatial distance. The cognitive advantage of incorporating a system that includes knowledge integration and problem solving prompts into distance education is that viewing materials from multiple perspectives can increase cognitive flexibility and interconnections as well as giving opportunities to share and become involved with the learning community.

Limitations of the Study

This study was primarily designed for undergraduate pre-service teachers and implemented in a web-based learning environment. Limited time was allocated to the students during the lab sessions. The one-hour period seemed insufficient for most of the students to absorb the information and apply it to the problem solving tasks. This was evidenced by the conversations between the researcher and some students after the study. While a longer time frame might have been more realistic for the instructional task, it also would likely have reduced interest in voluntary participation.

The contents and problem solving tasks were strictly related to educational measurement issues. This reduced the complexity of the knowledge and tasks. The scope of the problem seemed to be confined within educational measurement, which might not be sufficient to represent students' overall problem solving abilities. In the future, a more complex task should be provided in order to study how students' problem solving performance varies according to the level of complexity.

The next limitation was associated with the design of the experimental study. Given the pre- and post-study design, it would be hard to avoid the violation of independent observation assumptions. It was unavoidable whether students shared time with each other outside the study, and they might have unintentionally influenced one another's responses. Researchers need to continually address this problem in flexible and creative ways.

The other noticeable limitation is the use of concept map and talk-aloud protocols to understand students' knowledge acquisition. Most of the participants had little experience with constructing a concept map—this may have created a sort of image block for them. Instructions on how to create a concept map or illustrations of good and bad examples of a concept map may have helped students feel comfortable using such strategy to demonstrate their understanding of the concepts. Finally, the number of students that participated in this event limits generalizability.

Recommendations for Future Research

The research described herein raises several questions. The current study did not acquire information regarding how students' integrated knowledge evolved after they were prompted to undergo knowledge integration. It may be necessary to better clarify the theoretical bases for how knowledge integration evolves as well as how it can best be measured. Accordingly, it may be beneficial to examine and adapt methods used in other fields to better understand knowledge integration. For instance, a group of researchers used benchmark as one of the techniques to assess the process of knowledge integration (Lee, Husic, Liu, & Hofstetter, 2006). A mixed initiative assessment that includes humans and computers has been widely discussed and implemented in real, scaffolding classroom settings (e.g., Zimmerman, 2005). This dynamic assessment evaluates transitions in knowledge representations and performance while learners are in the process of solving problems, rather than after they have completed a problem, which is critical to provide valid interpretations of students' performance. A further investigation of assessing knowledge integration in the areas of cognitive psychology needs to be explored and discussed.

Further research regarding how students obtain knowledge should involve more complex real-world problems. In complex real-world problems, students can connect more of their prior knowledge or experience, which facilitates conceptual change and theory evolution. However, the design of any real-world problems should be modified according to students' learning curve. The investigation of the transition from simple to more complex problems may provide us more insights into the evolution of understanding.

Another avenue for future research is how knowledge is integrated and evolved through the use of other scaffolding techniques, such as cooperative group and expert modeling. Peer learning is assumed to promote sharing and the development of understanding. This study indicates that interaction and feedback loops may be useful in facilitating better knowledge integration. The web-based learning environment developed for use in this research was specifically designed to promote knowledge integration and problem solving through different types of question prompts. From a design perspective, it would be useful to know if other tools had a greater impact on students' knowledge integration than the question prompts (Chen & Ge, 2006). Knowing this might lead to more generalizable design principles for designing better knowledge integration environments. Research on this question would likely involve conducting interviews with students specifically regarding the use of tools, collecting pre-post analyses of knowledge integration, and tracking students' progress (e.g., time logs of overall frequency of use as well as frequency of specific tool use), and would provide valuable information.

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APPENDIX A

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

PROJECT TITLE:	**Prompting Knowledge Integration and Ill-Structured Problem Solving in a Web-Based Environment.**
PRINCIPAL INVESTIGATOR:	**Ching-Huei Chen**
CONTACT INFORMATION:	**820 Van Vleet Oval Room 321 Norman, OK 73019** **karenchen@ou.edu or 325-9651**

You are being asked to volunteer for a research study. This study is being conducted in the Instructional Psychology and Technology program in the Department of Educational Psychology. You were selected as a possible participant because you are a student enrolled in EIPT 3483. Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study
The purpose of this study is intended to investigate the effects of question promptings embedded in the web-based learning environment to scaffold the processes of solving educational measurement problems.

Procedures
The study consists of two sessions, which will be held one week apart in a computer classroom. In the first session, you will log into a web site with a pre-assigned password; then you will be presented with instructional passages and problems on educational assessment. The session takes about 1.5 hours. In the following week, you will come back to participate in the second session, during which you will be presented with another set of instructional passages and problems. The second session takes approximately 1.5 hours.

Risks and Benefits of Being in the Study
There are no risks to you for participating in this study. A benefit of taking part in the study is gaining problem-solving experience in educational settings and better understanding of educational assessment.

Compensation
In exchange for your time and participation in this study, you will receive research participation points from your instructor of the class from which you are being recruited. If you choose not to participate in the study, you will be informed of alternatives for receiving course credit from the instructor. There is no penalty if you choose not to participate or choose to stop while participating; however, to receive all the participation points you will need to attend both sessions.

Voluntary Nature of the Study
Participation in this study is voluntary. Your decision whether or not to participate will not result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free to not answer any question or to withdraw at any time.

Confidentiality
Records of participation in this study will be maintained and kept confidential to the extent permitted by law. All study materials will be identified with a code number. In the event of any report or publication from this study, your identity will not be disclosed. Results will be reported in a summarized manner, so that subjects cannot be identified. Findings will be presented in aggregate form with no identifying information to ensure confidentiality.

The records of this study will be kept private. In published reports, there will be no information included that will make it possible to identify the research participant. Research records will be stored securely in a password-protected server site and only approved researchers will have access to the records. The audiotapes will also be held in a locked cabinet. No one except the researcher will have access to the recordings.

Audio Taping Of Study Activities:
To assist with accurate recording of participant responses, interviews may be recorded on an audio recording device/video recording device. You have the right to refuse to allow such taping without penalty. Please select one of the following options.

☐ I consent to the use of audio recording.
☐ I do not consent to the use of audio recording.

Contacts and Questions:
You are encouraged to contact the researcher(s) if you have any questions. Ching-Huei Chen at 325-9651 or karenchen@ou.edu and Dr. Amy Bradshaw at 325-1530 or bradshaw@ou.edu.

If you have any questions about your rights as a research participant, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

STATEMENT OF CONSENT

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

______________________ Signature	______________________ Date

APPENDIX B
PRELIMINARY RESEARCH STUDY

Prior to the actual experimental study, a pilot study was conducted during Fall 2005. A total of 53 students participated. No significant differences were found among the types of question prompts on the dependent measure of students' knowledge acquisition F (3, 47) = .49, p = .70, η^2 = .03, observed power .14.

However, there was a difference among the types of question prompts on students' ill-structured problem solving outcomes, Wilks's Λ= .50, F (9, 110) =4.0, p= .000. The multivariate η^2 based on Wilks's Λ was quite strong, .21, and observed power was considerably high, .97. The significant differences fall under two subsets of ill-structured problem solving. The results reveal that there is a significant difference between groups on the subsets of developing solutions, F (3, 47) =3.38, p=.026, η^2 = .18, observed power .73, and evaluating and justifying a plan of action, F (3, 47) =6.50, p=.001, η^2 = .29, observed power .96. Overall, the knowledge integration group had the higher scores on developing solution (M=4.46, SD=.65) and justifying and evaluating a plan of action (M=4.85, SD=.57) than other groups.

In terms of problem representation, the procedural group performed better than the other groups (M=5.64, SD=.63). Additionally, the group who received both knowledge integration and procedural prompts had the lowest ill-structured problem solving outcomes compared to groups who only received either knowledge integration prompts or procedural prompts. Table B.1 contains the means and the standard deviations for the dependent variables for the four groups.

Table B.1
Means and Standard Deviations for Dependent Variables

Dependent variables	Problem representation	Developing and justifying solutions	Monitoring and evaluating a plan of action
Knowledge integration (KI) (n=15)	M= 5.08 (SD=.66)	M= 4.46 (SD=.65)	M= 4.85 (SD=.57)
Problem solving (PS) (n=14)	M= 5.64 (SD=.63)	M= 4.07 (SD=.62)	M= 3.00 (SD=.55)
Knowledge integration and problem solving (KP) (n=13)	M= 5.08 (SD=.66)	M= 3.54 (SD=.65)	M= 2.85 (SD=.57)
Control (n=11)	M= 3.37 (SD=.71)	M= 1.64 (SD=.70)	M= 1.18 (SD=.62)

In the qualitative results, two raters agreed that groups who received knowledge integration prompts tended to use concepts carefully and correctly. On the other hand, groups who did not receive those prompts tended to use concepts ambiguously. Examples from each group regarding their conceptual understanding of the concepts are presented in Table B.2.

Table B.2
Examples of Conceptual Representation

Group	Examples
KI	"Validity refers to the appropriateness of the interpretation of the results of an assessment procedure for a given group of individuals, not to the procedure itself."
PS	"A reliable and valid rubric will yield more accurate content assessment." "…if there were a clear set of criteria there could be more reliability since …." "I have some concerns on the validity of the rubric and the reliability of the grades the students will receive."
KP	"…test-retest action to analyze your reliability…" "…the project was not valid as well when appropriateness of interpretation of assessment result…" "…the purpose of reliability is to ensure that the tests that are given are consistent and do not vary in their form of results…"
Control	"…is grading the outcome of the project a valid means of assessing their knowledge and will the grades be reliable in determining what they know." "…it is good to come up with your own forms of grading to interpret the way you want, but make sure you rely on proven sources for your criteria." "…since …, you might want to compare students grades to another to check validity."

Analysis of interview data revealed that groups who received knowledge integration prompts believed that those prompts helped them think about different aspects/parts/relationships of things. Those prompts served as a stepway to understanding concepts and problem solving, activated their reflective thinking to pay more attention to important things, and organized and transferred concepts as they applied in real-world situations. Groups who received procedural prompts said that with these prompts they still had to spend time to pull the information together and also relied more upon their knowledge of the concepts instead of upon a process of solving the problems. One of the students responded that "I think they helped more in the problem-solving skill than the actual understanding of the concepts." However, these procedural prompts helped students zoom in on some of the important problems in the case studies, analyze the specific problem in-depth, and break down the problems into sub-problems.

APPENDIX C
TREATMENT MATERIALS

Knowledge Integration Prompts

Problem Solving Prompts

Pre-/Post-Experimental Tests

Ill-Structured Problem

Knowledge Integration Prompts

Narratives: The following prompts are designed to promote your understanding of the concept of assessment that you have just read. Please type your answers to each question in the text box provided. Your answers will be saved in the database, and you can retrieve them later. Again, think about these questions as thoroughly as possible, and give your best responses as these responses will help you in the task later.

1. Explain why reliability and validity are important to know about. Explain how reliability and validity can affect the test results and how they can be used in instruction.
2. What are the differences between different types of reliability and validity? How are different types of reliability and validity similar?
3. How do reliability and validity tie in with the effective design of instruction that you learned before? What happens if reliability and validity are not carefully considered?
4. How could reliability and validity be used to the design of test items for the students?
5. Go beyond what was covered in the instructional passages, and summarize the purpose and the meaning of reliability and validity. Also provide your explanation and justification for the statements you make.

Problem Solving Prompts

Narratives: The following prompts are designed to facilitate your thinking process in solving the problem. Please type your answers to each question in the text box provided. Your answers will be saved in the database, and you can retrieve them later. Again, think about these questions as thoroughly as possible, and give your best responses, as these responses will help you in the task later.

1. What facts from this case suggest a problem? What do you believe is the primary problem in how the teacher assessed her students? Why is it occurring?
2. What other problem(s) might be occurring as well? Why?
3. What are some specific examples from the case study that might help the teacher understand her assessment and measurement issues?
4. What specific strategies do you want to suggest to the teacher to help her solve the problems that you have identified in her class and to improve the way she evaluates her students?
5. Why do you suggest those strategies? Use examples or evidence to support your suggestions.

Pre-/Post-Experimental Tests

1. All of the following relationships between validity and reliability are possible except
a. high validity and low reliability
b. high validity and high reliability
c. low validity and low reliability
d. low validity and high reliability

2. The term reliability is closest in meaning to
a. consistency
b. objectivity
c. practicality
d. validity

3. The split-half method provides a measure of
a. equivalence
b. internal consistency
c. stability
d. stability and equivalent

4. The term reliability, as used in testing and assessment, refers to the
a. accuracy of test construction
b. method of test interpretation
c. test or assessment results
d. test or assessment instrument itself

5. Directions: For each of the following statements, indicate which method of determining reliability is being described by circling the appropriate letter using the following key.
Keys: A. Test-retest, B. Split-half, C. Inter-rater consistency, D. Alternative-form reliability
5.1. Determining whether test scores on school records are still dependable.
5.2. Determining whether an informal classroom assessment has internal consistency.
5.3. Evaluating the adequacy of judgmental scoring of performances on a complex task.
5.4. Seeking support for the adequacy of the sample of test items on two tests.

6. A teacher who assesses reliability of a test using the test-retest method is concerned with what type of reliability?
a. Stability
b. Equivalence
c. Internal consistency
d. Stability and equivalence

7. The results of assessment is interpreted as the followings EXCEPT
a. a limited measure of performance obtained at a particular time.
b. a reasonably consistent over different occasions.

c. identification of students' abilities.
d. prediction success in future learning activities or occupations.

8. Reliability is a sufficient condition for validity.
TRUE
FALSE

9. In order to get close to a true score, measures need to be tested twice with the same students, but without fatigue and memorizing the answers.
TRUE
FALSE

10. Standardized tests are more reliable and valid than teacher-made tests.
TRUE
FALSE

11. Reliability is higher when the estimated true score is more accurate.
TRUE
FALSE

12. Any particular instrument may have a number of different reliabilities, depending on the group involved and the situation in which it is used.
TRUE
FALSE

13. Which one of the following statements is true regarding the relationship between reliability and validity?
a. A test can be valid and not reliable.
b. A test must be reliable in order to be valid
c. A test must be valid in order for it to be reliable.
d. There is no relationship between reliability and validity.

14. Which of the following explanation best illustrates why some competitions (Ms. America, Gymnastics meet, ice skating) have multiple judges?
a. Multiple judges is the best way to ensure an internally consistent result.
b. Multiple judges allow for a better representation of a person's true score.
c. Multiple judges increase the performer's concurrent validity.
d. Multiple judges allow for interrater reliability estimates.

15. A researcher uses split-half reliability to estimate the reliability of a recently constructed self-efficacy instrument. The researcher determines the reliability to be .92. Which of the following claims can that researcher make regarding his estimate of reliability?
a. The results are a good predictor of future self-efficacy.
b. The results seem to be highly stable over time.
c. The results have a high degree of equivalence.

d. The results are internally consistent.

16. Directions: Write down which of the following statements concerning validity are correct as C and which are incorrect as I.
16.1. Validity refers to the test itself, not just the test scores.
16.2. Validity is a matter of degree (e.g., high, low).
16.3. Validity refers to how consistently a test measures something.

For question 17-19, indicate which of the following types of validity evidence is being gathered.
17. Subject-matter experts have been called up to rate the consonance of a test's items with the objectives the test is supposed to measure.
a. Content-related evidence of validity
b. Construct-related evidence of validity
c. Criterion-related evidence of validity

18. A correlation is computed between a new test of student self-esteem and a previously validated and widely used test of student self-esteem.
a. Content-related evidence of validity
b. Construct-related evidence of validity
c. Criterion-related evidence of validity

19. Scores on a screening test (used to assign college sophomores to standard or enriched English classes) are correlated with English competence of college juniors (as reflected by grades assigned at the close of junior year English classes).
a. Content-related evidence of validity
b. Construct-related evidence of validity
c. Criterion-related evidence

Ill-Structured Problem

Instruction: Your task is to email Mr. Fishbein about the validity and reliability of the grades based on the project. Feel free to refer to the Glossary page and you may refer to See Your Previous Responses to the Case Study that you completed earlier to assist you as you complete this task. Copy and paste if necessary.

Case Scenario:

Mr. Fishbein is a very creative new teacher who teaches second grade. He loves to show his students how the different subject areas all compliment one another, so he presents new concepts in multiple ways. He tries to show connections with math, science, reading, and art. He uses a lot of group activities and work-alone projects as opposed to teacher-directed lessons.

One of Mr. Fishbein's more exciting units was on animals of the ocean. The main unit was a part of the science curriculum, but he had them count different fish and other species in math and compare current counts to those of 50 years ago. He also had them read stories about different types of sea animals. Of course, they all had seen "Finding Nemo" and were excited to talk about the animals in that particular movie. He additionally had them work in small groups to construct an artistic rendition of a fish or sea animal of their choice using any type of material that they wanted (e.g., clay, paper, paper-maché). The project was worth 500 points for each student in a group, but not all the children seemed to work together in their group on the project. Mr. Fishbein had constructed a scoring rubric, but he had not tested it out yet.

APPENDIX D
STUDENT SELF-REPORT ON THE RESEARCH STUDY

Perceptions of Text Passages and Prompt Types

Perceptions of the Web-Based Instruction on the Ease of Use/Navigation, Interests, and Cognitive Overload

Perceptions of Text Passages and Prompt Types

Directions: The following questions ask about some of your perceptions of this study. Respond to the statements along the following 6-point scale.

1	2	3	4	5	6
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree

1. Regarding the text passages (for all conditions)
a. This instructional text required concentration.
b. Reading the instructional text required complex thinking.
c. I did not have to think very hard when reading the text.
d. During some parts of the text readings, I felt I had to hold too much in my head at one time.
e. The language used in the text was complex.
f. The information included in the text was complex.

2. Regarding the question prompts that followed the text passages (for KI and KP conditions)
a. Completing the questions required me to think a lot.
b. Answering the questions required concentration.
c. Using the questions required complex thinking.
d. These questions helped me check my understanding about the concept of reliability.
e. These questions required me to hold too much in my head at one time.
f. I did not have to think very hard when answering these questions.

3. Regarding the question prompts that followed the case study (for PS and KP conditions)
a. Completing the questions required me to think a lot.
b. Answering the questions required concentration.
c. Using the questions required complex thinking.
d. These questions helped me check my understanding about the concept of reliability.
e. These questions required me to hold too much in my head at one time.
f. I did not have to think very hard when answering these questions.

Perceptions of the Web-Based Instruction on the Ease of Use/Navigation,

Interests, and Cognitive Overload

Directions: The following questions ask about some of your perceptions of this study. Respond to the statements along the following 6-point scale.

1	2	3	4	5	6
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree

1. Keeping the lesson content in mind while navigating this site was difficult.
2. In terms of navigation, this lesson was simple to use.
3. The navigation and layout of this site made it easy for me to concentrate on the lesson content.
4. In terms of ease of use, this lesson was simple.
5. In terms of navigation, this lesson could have been made easier to use.
6. My level of interest remained steady throughout this module.
7. I thought the scenario regarding Mr. Yeates (session 1) was more interesting than Mr. Fishbein (session 2).
8. Reliability and validity are interesting topics.
9. I think my level of interest in reliability and validity affected how well I solved the problem.
10. My interest in reliability and validity has increased since using this module.

11. Indicate the amount of mental effort (brainpower) you have spent on the module. Select the corresponding number below.

1	2	3	4	5	6	7	8	9
Very, very low mental effort	Very low mental effort	Low mental effort	Rather low mental effort	Neither low nor high mental effort	Rather high mental effort	High mental effort	Very high mental effort	Very, very high mental effort

APPENDIX E
SCORING RUBRIC FOR ILL-STRUCTURED PROBLEM SOLVING

1. Problem Representation (15 points max.)Score: _______

1.1 Define the problem.

Examples for reliability: 1. rubric has not tested elsewhere. 2. single measure doesn't provide any consistent results. 3. lack of inter-rater reliability in terms of scoring method.

Examples for validity: 1. evaluation of group work is not adequate and appropriate to demonstrate students' achievement (individuals get points same as group when groups not functional; it's not fair). 2. Points for rubric seem excessive.

5 Identify 3 problems in reliability and 2 problems in validity.

3 Identify 2 problems in reliability and 1 problem in validity.

2 Identify only 1 problem in reliability and validity.

1 Identify only 1 problem in either reliability or validity.

0No problem identification**.**

1.2 Generate relevant factors for problem representation.

Examples: other factors besides the selection of test method can affect reliability and validity, such as external factors (e.g., sickness, social problems, peer influence, home problem) and internal factors (e.g., test anxiety).

5 High: Analyze from both external and internal aspects.

3 Mid: Analyze from only one aspect.

1 Low: analyze from other aspects besides internal or external.

0 No analysis of any aspects

1.3. Construct argument for problem representation.

5 High: strong argument for both reliability and validity

3 Mid: strong argument for only reliability and weak in validity

1 Low: weak in both reliability and validity

0 No argument at all.

2. Develop solution(s) (15 points max.) Score: _______

2.1 Selecting or developing solutions.

Examples for reliability: 1. Find an existing and reliable scoring rubric. 2. adopt other test methods, for example, standardize tests, 3. have multiple raters score the group project.

Examples for validity: 1. individually based projects and grade each individually. 2. Decrease the amount of points for group projects.

5 Develop 3 for reliability and 2 for validity.

3 Develop 2 for reliability and 1 for validity.

1 Develop 1 for reliability.

0 No mention of solutions.

2.2 Evaluating solution(s).

5 High: strong argument for both reliability and validity

3 Mid: strong argument for only reliability and weak in validity or vice versa

1 Low: weak in both reliability and validity

0 No argument at all.

2.3 Consider alternatives for solutions.

e.g., the instruction is clearly explained. Grouping method (dynamic?).

5 Select alternative solutions and clearly explain the reason

3 Select one alternative solution and provide explanations

1 Select alternatives without explaining the reason

0 Lacking: No mention of alternative solutions

3. Generate a clear link from proposed problems to proposed solution (s), in other words, monitor and evaluate a plan of action (10 points max.)
Score: _______

3.1 Provide evidence for overall linkage (overall soundness).

5 High: The methods and data sources show a clear link to problem representation.

3 Mid: The methods and data sources show some link to problem representation.

1 Low: The methods and data source show vague link to problem representation.

0 Lacking: No link at all.

3.1 Provide evidence for overall linkage (overall flow).

5 High: The email shows high level of organization and integration.

3 Mid: The email shows some level of organization and integration.

1 Low: The email shows weak organization and integration.

0 No organization and integration at all.

APPENDIX F
SAMPLE TRANSCRIPTIONS

Sample Concept Maps (John, Michelle, Molly)

Sample Talk-Aloud Protocols (John, Michelle, Molly)

Sample Interview Transcripts (John, Michelle, Molly)

Sample Data Analysis (John, Michelle, Molly)

Sample Concept Map

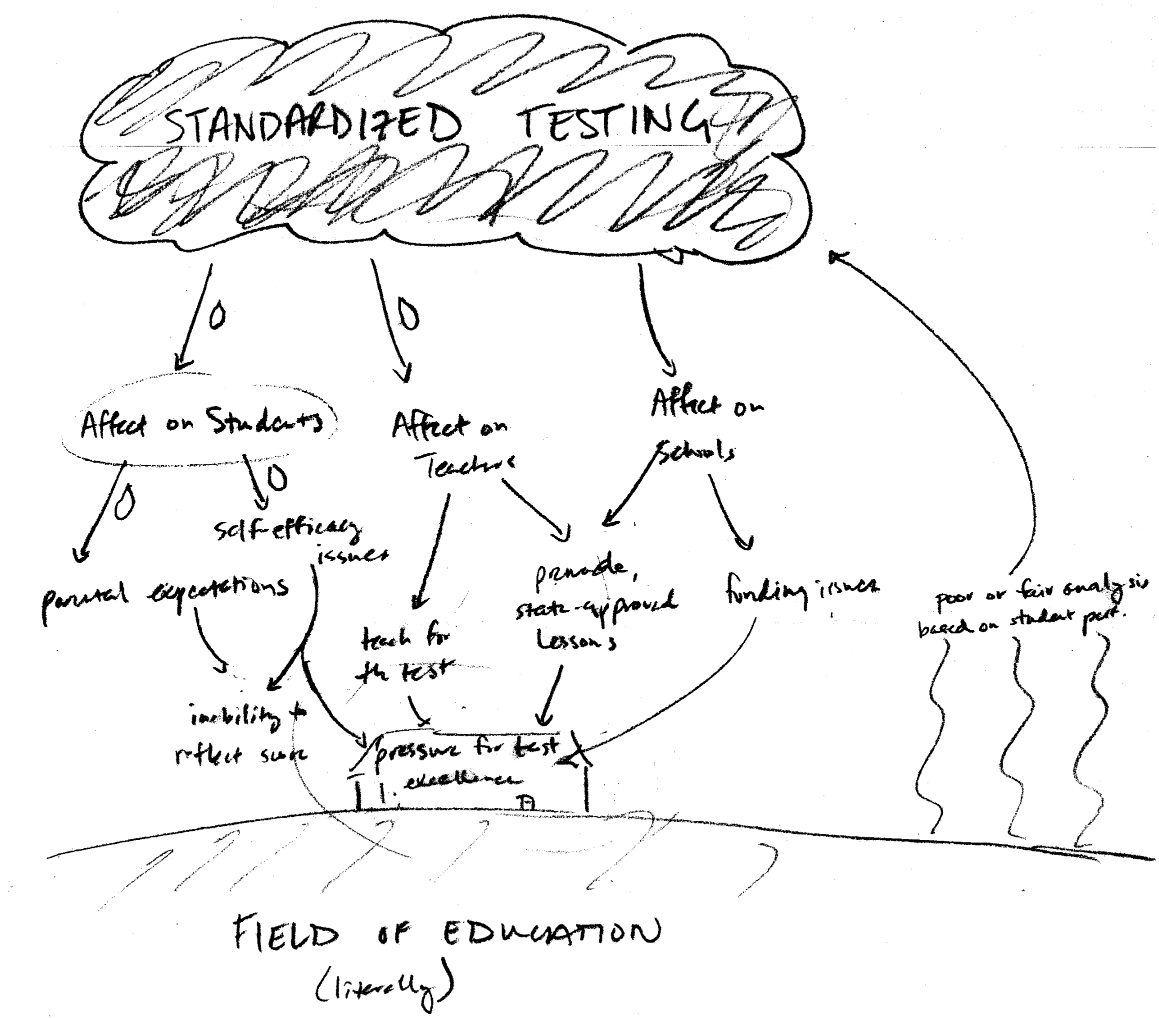

Figure F.1 Pre-Experiment Concept Map (John: KI)

Sample Concept Map

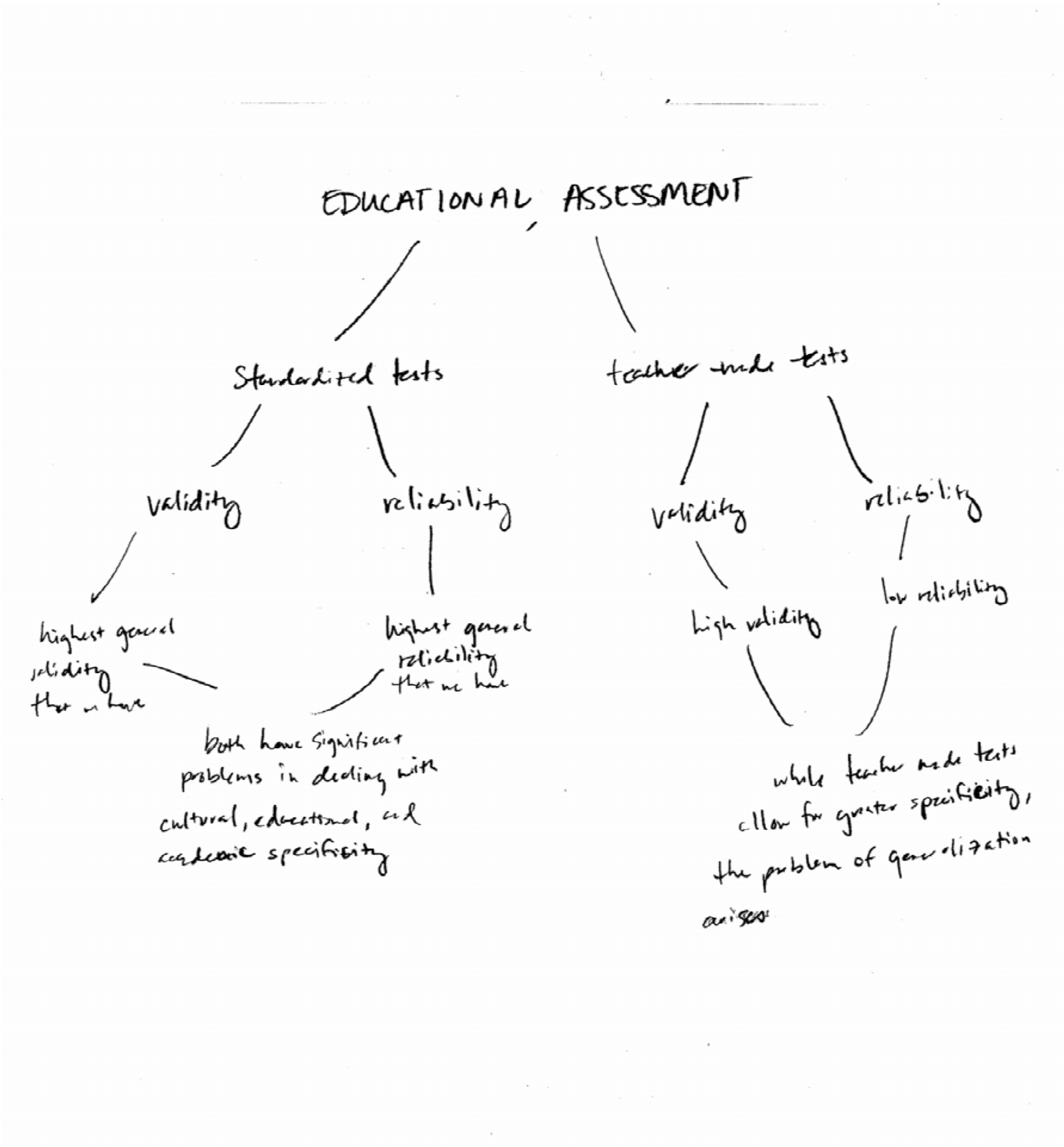

Figure F.2 Post-Experiment Concept Map (John: KI)

Sample Concept Map

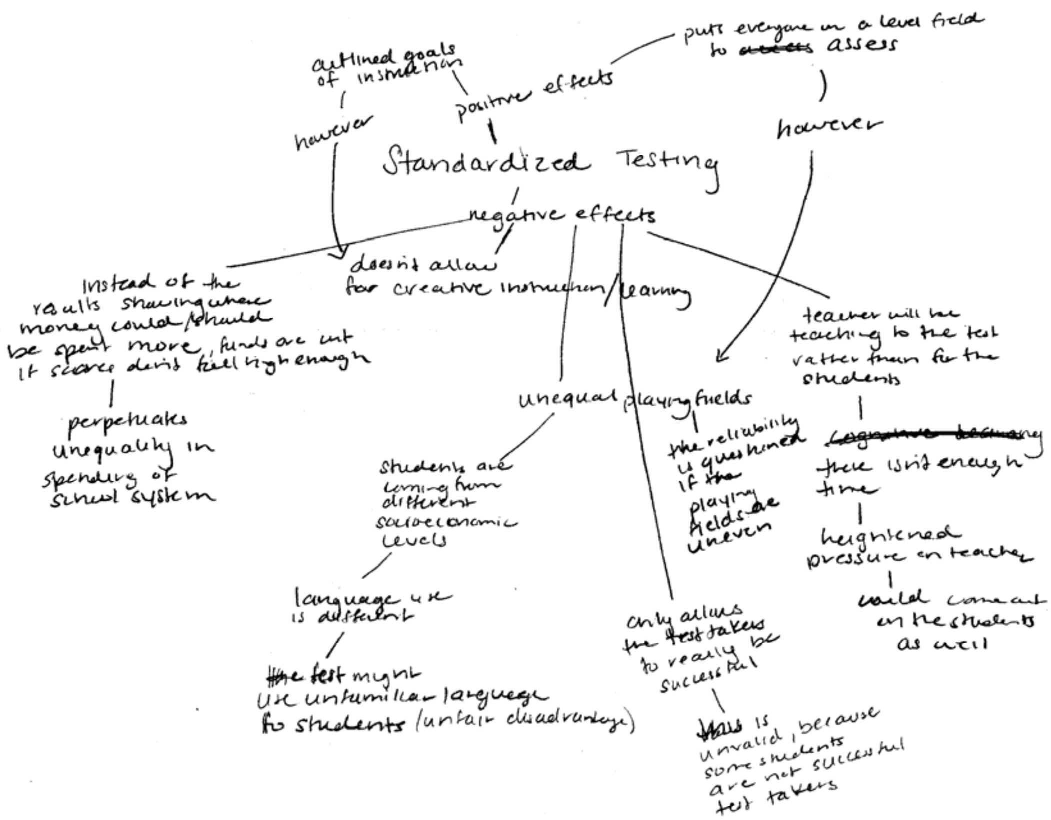

Figure F.3 Pre-Experiment Concept Map (Michelle: KP)

Sample Concept Map

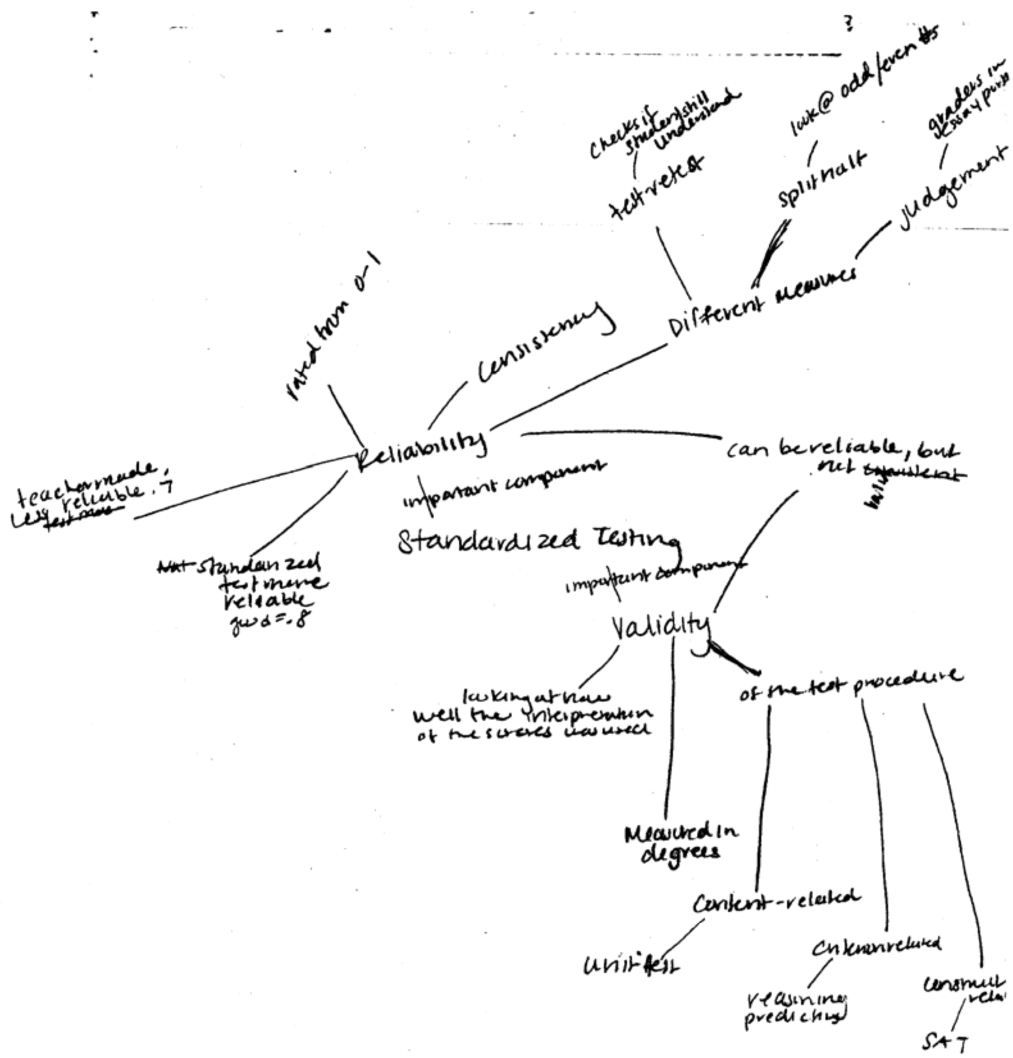

Figure F.4 Post-Experiment Concept Map (Michelle: KP)

Sample Concept Map

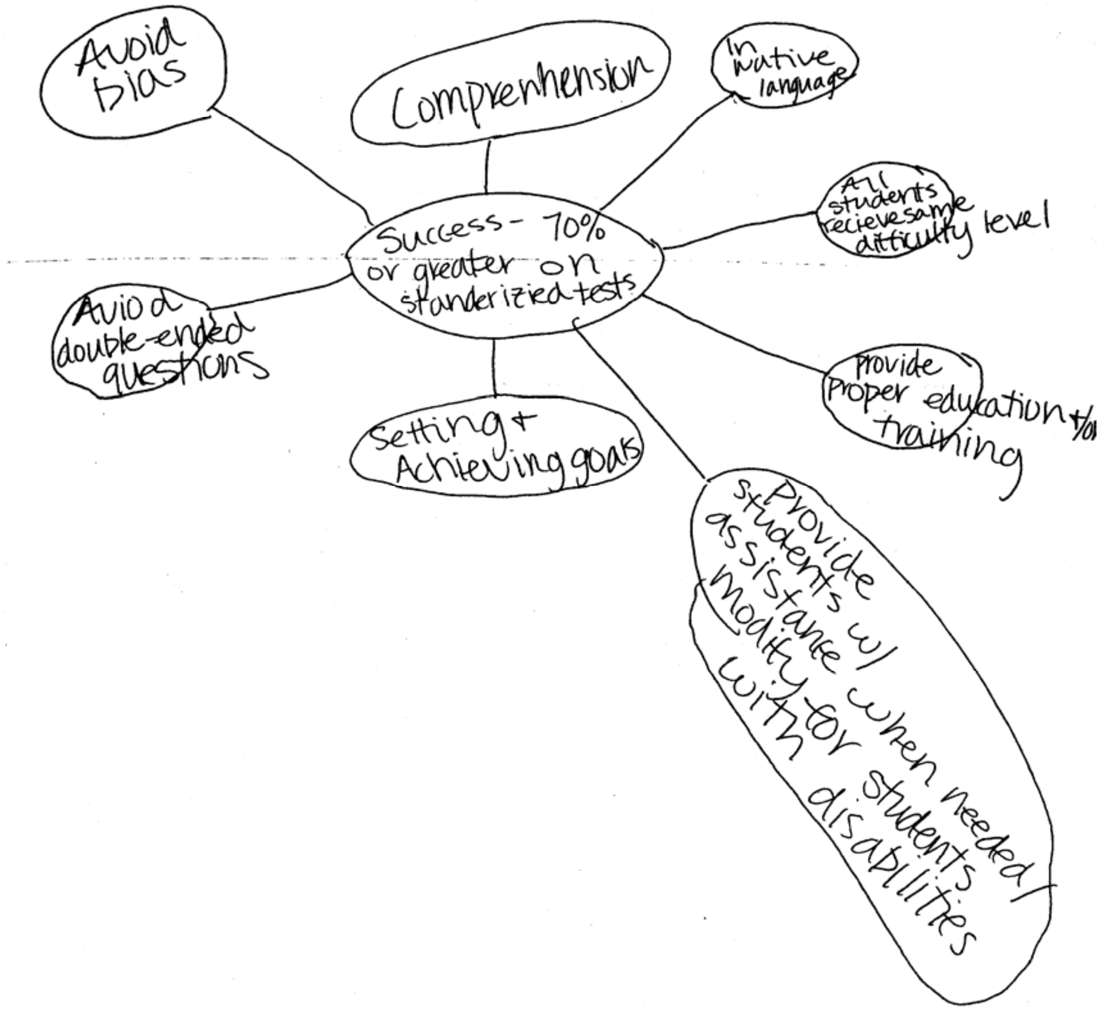

Figure F.5 Pre-Experiment Concept Map (Molly: Control)

Sample Concept Map

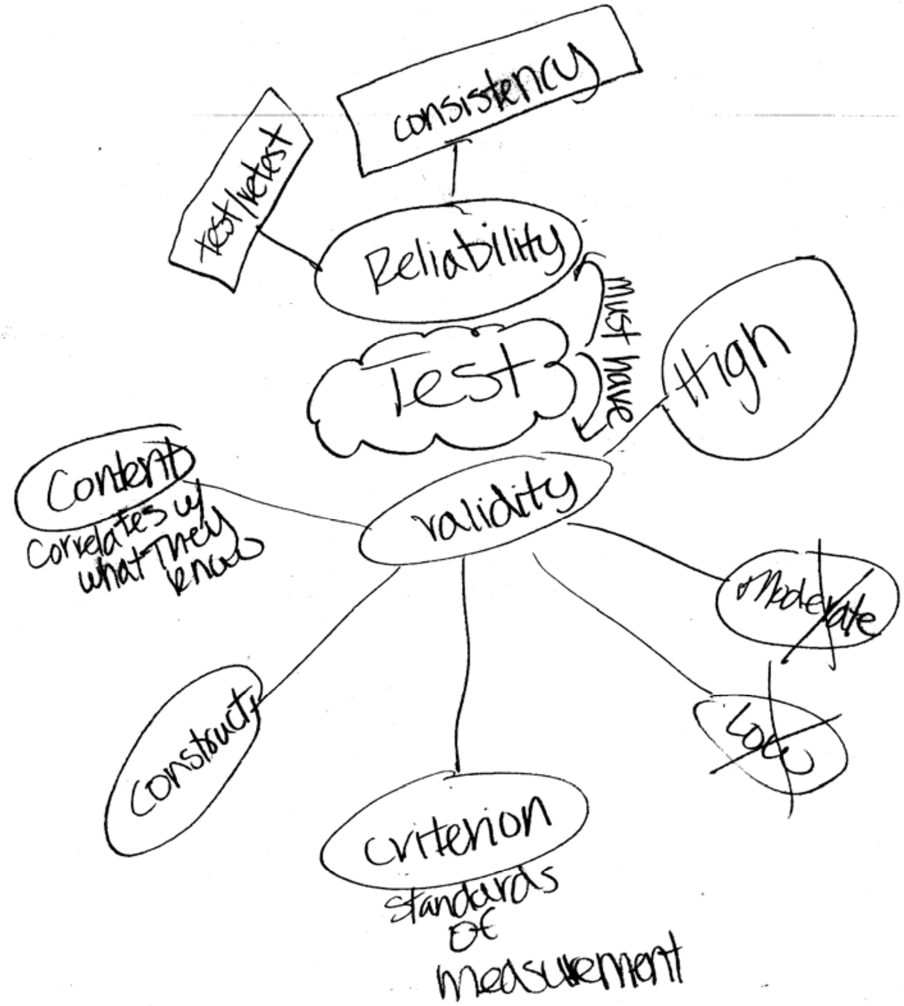

Figure F.6 Post-Experiment Concept Map (Molly: Control)

Sample Talk-Aloud Protocols

Participant: John
Condition: Knowledge Integration

<u>Transcriptions: (RE: Researcher; PA: Participant)</u>

RE: Can you explain (participant laughs) to me your map.
PA: I hope so, it's really uh conduluded, but when I, when I try to think of it what I try to do was get a mental image, normally you're gonna do the concept map to the connecting lines, different ideas and how they connect, etc. etc, but I always need some kind of overall illustration, I guess, to understand everything. So, I've got standardized testing in this black cloud
RE: mhmm (while participant is talking)
PA: which is an ambiguous good bad symbol,
RE: mhmm (while participant is talking)
PA: rain, but then again rain.
RE: mhmm, ok (while participant is talking)
PA: (participant coughs) Well, arrows are dropped, that will just help me, so you will understand, you know, where it's going, where it's flowing, what I'm doing.
RE: Ok
PA: Uh, so, you've got branching under the three different major effects of standardized testing, students, teachers, schools.
RE: Ok
PA: And you've got the students breaking off into smaller raindrops more or less (participant laughs).
RE: Ok, so, this one is a raindrop?
PA: Yah, the lines represent raindrops. I just put it on a couple of them to uh keep the image fresh in my mind (participant laughs).
RE: Ok, uh huh
PA: But, uh, you got the effect on students, you got parental expectations, and self advocacy issues.
RE: mhmm mhmm
PA: And uh, this will branch off into the inability to reflect the score
RE: mhmm (while participant is talking)
PA: Uh in the classroom and the parental expectations of why is the child not of able to, you know, my child scored you know a migillion on this standardized test, why aren't they brilliant in school?
RE: mhmm
PA: Same thing with the effect on teachers. You know teachers breaks off into teaching for the test and pre-made state approved lessons.
RE: Ok
PA: Uhh schools, funding issues, state approved lessons, and they all break down to pressure for test excellence.
RE: mhmm
PA: So, you've got the field of education, basing everything, the only thing that's getting any worry or any work is the pressure for test excellence.
RE: Ok
PA: And then the evaporation, if you will (while laughing), is the only thing the standardized test people are getting back is poor, fair analysis based on student performance.
RE: Ok
PA: All these factors
RE: Ok, so how does, umm, so umm like briefly, tell me about uhh, using your own definition, and uh how do you, um what is reliability means to you?
PA: Reliability, means, uh, the ability for a student overtime to perform the same way to, for educational measurement, to be uh universal and consistent with students.
RE: Ok, how 'bout validity?
PA: Validity (long pause) is, hmm (long pause). Validity is for accurate representation of what a student can truly do.

RE: Ok
PA: Uh not just based on circumstances.
RE: Ok, then how did, how do you think of the relationship between those two?
PA: Reliability and validity are (long pause), it would be nice if they would both be together in abs, in you know perfect form. But
RE: mhmm.
PA: Um
RE: Do you think one is necessary for the other, or?
PA: Validity uh helps reliability, cause the stronger and more pure, I guess, a test is…
RE: Ok (while participant is talking)
PA: the more liable the results are, but reliability doesn't necessarily need validity.
RE: Ok
PA: As much
RE: Alright
(background talking to researcher, researcher answered question)
PA: Uh you can have… uh validity doesn't have to be there because uh you can have a wrong answer a thousand times and accept that.
RE: Ok, ok, alright. So, um, you mention about the teachers, um, so you are saying that standardized testing will influence the teachers
PA: Yes, teachers (while researcher is talking)
RE: or have an affect on teachers?
PA: And this is what the effects are, specifically, some effects.
RE: Ok, and can you talk about uh um the reliability issues in standardized test?
PA: The reliability issues are, that, uh a child comes to the test hungry one day and it's going to mess up his or her performance.
RE: mhmm (while participant is talking)
PA: A child comes after a night of bad sleep or a night of exceptional sleep,
RE: mhmm (while participant is talking)
PA: or a wonderful breakfast, you know, different factors on that day and different factors that entire week could drastically affect the outcome of a student's performance.
RE: Ok, and how about the validity issue in uh standardized testing?
PA: Validity issue, the problem is, sometimes uh, every kid knows that sometimes if you don't know the stuff you can work the test,
RE: mhmm (while participant is talking)
PA: Which is you know, you look for the answers, you know, you do the little tricks, you know,
RE: mhmm (while participant is talking)
PA: or you just plain guess.
RE: mhmm (while participant is talking)
PA: and, which screws up validity because if the child isn't even trying
RE: Ok (while participant is talking)
PA: you can't get a valid response.
RE: Ok, alright. So, do you think standardized test has more reliability or validity or not enough of both?
PA: Not enough of both
RE: Ok (while participant is talking)
PA: but it's the best that I've got so far.
RE: Ok
PA: So, until we come up with something better, it's, it's like I said, so I put in the rain clouds to remind myself, you know, even though it's not exactly the best thing out there,
RE: mhmm (while participant is talking)
PA: it's all we got right now.
RE: Ok (while participant is talking)
PA: until some, until we come up with something better we, you know, just gonna have to live with it.
RE: Ok and how do you think about the teacher made test?
PA: The teacher made test?
RE: Mhmm
PA: Uhhh

RE: Their reliability and validity
PA: I think the reliability it, it all depends on the teachers you get,
RE: mhmm (while participant is talking)
PA: because, well if you are a different group of teachers for each state it's going to drastically change.
RE: mhmm (while participant is talking)
PA: But, uh, validity, I think would be much, much stronger with that,
RE: Ok, ok (while the participant is talking)
PA: Because uh the teachers would know what to do, the teachers would know what their students are strong in what they're poor in.
RE: mhmm mhmm
PA: Which goes back to reliability, the teachers could just mark the test to make it, easy (while laughing).
RE: Ok, alright. Thank you, that's all. Do you have anything else that you want to explain to me about the map?
PA: No.
RE: Ok, alright. Thank you.

Sample Talk-Aloud Protocols

Participant: Michelle
Condition: Knowledge Integration and Problem Solving

Transcriptions: (RE: Researcher; PA: Participant)

RE: I would like you to say your first name, first.
PA: Ok, Michelle
RE: Ok, alright. Um, Michelle, can you tell me about your map?
PA: Yes, ok what I did was, (stuttered on the word standardized), standardized testing went in the middle and I wanted to break it up between the positive effects of standardized testing, or the positive outcomes, or you know just positiveness, I guess,
RE: Ok (while the participant is talking)
PA: of standardized testing, and the negative. Um first I'll go into positive, since there's not much there.
RE: mhmm (while the participant is talking)
PA: Um, first I said um, that there's outlined goals of instruction that the teachers know exactly what, you know, to teach to. And then I put, um puts everyone on an a level playing field to assess, so if everyones taking the the test,
RE: Ok (while the participant is talking)
PA: then um puts it on a level playing field. However, uh both these positive goals are actually not that positive but, because um as we go into the negative effects um we it doesn't allow, standardized testing doesn't allow for creative instruction and learning
RE: mhmm (while the participant is talking)
PA: just because you're going right
RE: mhmm (while the participant is talking)
PA: to the standardized testing, so that refutes the outlined goals of instruction.
RE: mhmm (while the participant is talking)
PA: And then um also it actually gives unequal playing fields um and the reasons for that are students are coming from different social, economic uh levels,
RE: mhmm, mhmm (while the participant is talking)
PA: and the language is different, the lang, language used on the test is different.
RE: Yeah (while the participant is talking)
PA: Um and also the test um might use unfamiliar language, so this is an unfair disadvantage.
RE: mhmm, mhmm (while the participant is talking)
PA: Um also with unequal playing fields I just said, that the this, the reliability is questioned if the playing fields are uneven,
RE: mhmm (while the participant is talking)
PA: um uh because then it's not very standardized (the participant and researcher laughed). And then another negative effect um is only allows um the test takers, the students that are test takers
RE: mhmm (while the participant is talking)
PA: to really be successful and that said this is um unvalid because uh some students are just not successful um test takers.
RE: mhmm (while the participant is talking)
PA: Also the negative effects, um, uh teachers uh will be testing to the test rather than for the students, and um that there isn't enough time,
RE: mhmm (while the participant is talking)
PA: um and also uh heightened pressure on the teachers which could come out um on the students as well.
RE: mhmm (while the participant is talking)
PA: Um also for negative effects um, instead of the results showing uh where the money could or should be spent,
RE: mhmm (while the participant is talking)
PA: um more funds are cut if scores um don't fall high enough. And then I said along with this it perpetuates inequality in uh spending of school system.
RE: Ok (while the participant is talking)

PA: So, I think that hits um all the points of standardized testing.
RE: Ok, um I would like you to ask you about um, can you give me um, I know this haven't been taught in the class,
PA: mhmm (while the researcher is talking)
RE: but I would like you to kind of give me uh, in your words, tell me about what reliability and validity means to you.
PA: Um, as far as, in as far as standardized testing goes, or just in general?
RE: In general.
PA: Ok, um if something is reliable
RE: mhmm (while the participant is talking)
PA: then um, it's, you can go to it no matter what, that um it's, it should be, um, I think reliability and validity kinda go together
RE: Ok (while the participant is talking)
PA: because um uh if something is valid, it is true, it is um, I don't know, it's, it's honest, it doesn't have any waivering in it. Um and then um for reliability you'll want to um I guess go to that thing, if something is valid, then you can rely on it, so.
RE: Ok, so, so you think these two has very close relationship
PA: Yes
RE: One, like if, so, so you are saying if we have low reliability then we will we will not have high validity.
PA: Or if we don't have high validity, we'll have low,
RE: Ok (while the participant is talking)
PA: if we have low validity then we will have low reliability.
RE: Ok, alright. Um I would like you to um, tell me about a little about standardized testing and the, the teacher made tests.
PA: The teacher made tests?
RE: Uh huh
PA: Ok
RE: And, you, what, in, you know, uh which one do you think is more reliable, has more reliability or validity.
PA: A teacher made or?
RE: Both, I would like you to discuss them.
PA: Oh, for, so, for a teacher, like if the teacher makes the standardized test? I'm sorry.
RE: Uh the teacher made test, which, you know, um sometimes the teacher, they create their own tests
PA: mhmm (while the researcher is talking)
RE: for their students.
PA: mhmm (while the researcher is talking)
RE: and I would like you to, ask you about, how do you think of those tests,
PA: Ok (while the researcher is talking)
RE: in terms of their reliability and validity.
PA: Ok, um, I think that um, that the teacher will probably know her students well and know uh what shes taught and what shes focused on. And so um, I'd say that, um, the reliability for that teacher, for that particular class would be high
RE: Ok (while the participant is talking)
PA: and that it would be a valid um uh form of, uh I guess um, testing them, I guess,
RE: Ok (while the participant is talking)
PA: because she would know what shes taught and um what they've covered, what the students have covered.
RE: Ok, so you are saying the teacher made tests are more reliable and valid than the standardized tests.
PA: Yes
RE: Ok, alright. Um that's all the questions I have, thank you.

Sample Talk-Aloud Protocols

Participant: Molly
Condition: Control

Transcriptions: (RE: Researcher; PA: Participant)

PA: Well, it says here, you know, the issues about educational measurement, what's a good way to um measure it, and I was thinking just the most obvious, just doing well on the standardized test. And I said, you know, over a seventy percent rate. And then I, for reliability and validity, you know, trying to make the test in the native language, so it's not uh understanding of the reading. Um all the students that I have taught, you know, they all need to have the same education, they need to know the same things, try to make sure everybodys on the same kinda background page, so it's not, you know, one type of, or one classroom knowing more than the other one, trying to test them over something. Um, for this one, I'm a special education major, so I think it's important to modify when needed, so if that's extended time or, you know, with an aid, I think that's important whenever it's stuff like this. I also said that it's important, you know, more than just a test, it's important that we have different ways to show comprehension, just in case students aren't the best at, you know, doing tests, doesn't mean they're not understanding things. Um, I tried to say to avoid bias and avoid, you know, double ended questions, just to kinda, if it isn't a standardized test, just more reliability or validity, I guess.
RE: Ok, ok. So, in, in your definition, um what do you think reliability means and validity means?
PA: Well, I think reliability means, that, I used, gah I used to know these things, I used to, I took a statistics course so long ago.
RE: Really?
PA: But I think, doesn't one of 'em mean, just the fact that the test is gonna hold true in other places, it's not just valid for that one time you took it, it's like that's a test it's gonna work in different places for different students.
RE: Ok
PA: And then I can't remember what reliability means (participant laughs).
RE: Ok, ok.
PA: Is that ok?
RE: Yeah, that's ok. So, you, you say the test gonna hold um
PA: Hold true, it's not gonna (while the researcher is talking)
RE: The validity. Do you say that's validity?
PA: Yeah
RE: Ok, well I just want to know um, how you know that, and uh, because later when you go to, log into the website, and the websites gonna, you know, give you some information about reliability and validity for the session 2, so and that's why I ask you. Um, so what do you think of the two, these two concepts relationship?
PA: Between validity and reliability?
RE: Yeah, do you, do you think both are necessary or that mean, or you can just have one or the other?
PA: No, I think both are necessary for you to have a true test of whether a student understands something. If we're talking about educational measurement, if you don't have a reliable, a reliable, or valid, valid test, then how are you gonna know if it's actually stating truth, or if it's not just a bad test? It's kind of an accountability towards the teacher, or the, you know, whoever is handing out the test, that this is gonna be, this is actually gonna be a true showing of how the students doing.
RE: Ok. And on the map you mention about standardized test and how do you think about standardized test in terms of um its reliability and validity?
PA: Well, I don't want to say that it's, that it's not completely reliable, because I know there's tons of people who sit there and work on the test, strictly to make it reliable, you know (participant laughs), or to have reliability and validity. So, I'm sure that, it's as about as close as it possibly can be. Like I said before, I think it's unfair that, you know, students at maybe an intercity school who aren't receiving the same education as somebody in, you know, a rich, suburban area, you know, have to take the same test. But unfortunately, that's how it works. But I think the test makers really try hard to make it, um have reliability and validity.

RE: Ok and how about those teacher made tests?
PA: The teacher made tests?
RE: Yeah
PA: I think those have a better chance, I mean those have a less of a chance to having these cause I think it's easier for just one person to maybe throw some bias in there, or maybe, you know, give too hard or too easy of a test, when, you know, you need to try to make sure you are testing on the right level.
RE: Oh, ok. So you are saying the teacher made test has less reliability and validity?
PA: I think so, depending on the teacher, unless they're really conscious of making sure it's testing the right level and making sure they're aren't any biases and stuff like that.
RE: Ok, alright. Um I guess that's all the question I have.
PA: Ok

Sample Interview Transcripts

Participant: John
Condition: Knowledge Integration

Transcriptions: (RE: Researcher; PA: Participant)

RE: I want to know about your experience in the study. Do you remember like right after text passages there, uh you know, a series of questions asking about how you understand it. Do you think those questions help you to um to better understand the concepts?
PA: Oh yeah. I, I think the uh, I think the essay ones, the ones where you got write it out, help me a lot more because the, the multiple choice you, you found the answer but you didn't really elaborate on it. And with the uh essays and especially the case studies, I got to uh apply it and through application and elaboration, I really understood it and really got more excited about it.
RE: Ok, so do you think those questions also help you in the problem solving?
PA: Oh, most definitely.
RE: Ok, alright. Um, so um, so what do you, what do you see as the greatest benefit of using those questions, of those questions besides helping you to see the application part, do you have anything else to say?
PA: Yeah, uh, allowing me to draw the ideas together and fully cement it in my mind.
RE: Ok (while the participant is talking)
PA: Uh you go in there with, with vague ideas of what reliability and validity are and you get the text passages and they're all jumbled up until you construct them in your mind and, you know, add to the new schemas and add to the old schemas and shift stuff around. You know, all that technical jargon aside, it's, it's really pretty good (the participant laughs).
RE: So, um, in terms of the problem solving, um, what was your approach in solving those, in solving those problems, I mean this week and last week? What was your approach?
PA: Uh, the approach last week was, uh was really trying as hard as I could to understand the text and then, I guess just trying to (long pause), to not so much regurgitate it back on to the page, but uh to, to write it in a way that someone, whoever wrote that, knew that I understood it and I was learning from it.
RE: Ok (while the participant is talking)
PA: And this week was just pretty much try to remember what I learned last week (participant laughs) and, and do that again.
RE: Ok, alright. Um, so, I mean I have another question about the, those problems.
PA: mhmm (while the researcher is talking)
RE: Um, do you think those problems, um, I mean, do they, do you think they are distracting, or do you think you have to, you know, put a lot of mental effort to, and think very hard on that?
PA: I don't think they were distracting.
RE: Ok (while the participant is talking)
PA: They, they were helpful, but you did have to put a lot of mental effort, I did at least, I don't know about anybody else, but to, to actually work with it you had to, some of 'em, like the listing ones though, like you know, list the similarities and differences that was horribly and mentally taxing, that was ok, this has this, this has this, this has this.
RE: Ok
PA: But helps to organize
RE: Ok, great. I have one more last question.
PA: mhmm (while the researcher is talking)
RE: Um, in terms of the, whole website, the whole study, the, the content, um what do you like or not like about it? You can talk about anything.
PA: Um, uh, I liked it was really easy to use and that's always a plus with websites because um, they can get pretty complicated (participant laughs).
RE: mhmm (while the participant is talking)
PA: Um
RE: Are there things you don't like? (while the participant is talking)
PA: Just keep trying.

Sample Interview Transcripts

Participant: Michelle
Condition: Knowledge Integration and Problem Solving

Transcriptions: (RE: Researcher; PA: Participant)

RE: I have a couple more questions that I want to ask regarding to the whole study. You had the chance to experience two different types of question prompts. And you were prompt to answer those questions. One, one prompt is specifically is right after the, you reading the text passage and the other type of prompt is for your problem solving. I would like you to tell me about your experience about these two types of prompts? Do you prefer and which do you think is more difficult for you?
PA: Ok, I think, I really like the questions right after the text message and then about the understanding um and asking for examples because then, you know, if, if I read it, and I thought I understood everything and then you'd ask a question and I'd be like well, I don't know and so I would have to reread again and I think it better guided my understanding. And the uh problem solving though, I really could, I enjoyed though because it allowed me to use what I'd just learned and making sure that I could actually apply it to a real classroom situation.
RE: So, do you think, if you were gonna, if you were asked to do this again, which prompts do you think you prefer or do you prefer both?
PA: Um, I, I think both go hand in hand, but I think the problem solving's probably even more relevant, so we can use it for um, you know, applying to our lives and seeing how it applies to our lives.
RE: Ok, so you think the problem solving problems is more helpful to you?
PA: Well I, well I think it, I think the questions right after the text probably are more helpful to me, but overall I think it's important to, to make sure it applies to real life.
RE: Ok and the next thing I wanna ask you is about your um, in terms of your mental effort.
PA: mhmm (while the researcher is talking)
RE: And by mental effort I mean um, the, the, your cognitive processing.
PA: mhmm (while the researcher is talking)
RE: And which type of problems help you to, you know, uh or not help you, but kind of give you overload on your cognitive processing?
PA: They are harder, or?
RE: Yeah.
PA: Ok
RE: Which do you think is harder?
PA: I think the problem solving is hardest because um, cause I was like um, like uh especially the end one we had to use both reliability and validity I was, it was hard for me to be like ok wait, what, like what was reliability and what was validity.
RE: mhmm (while the participant is talking)
PA: And so, I think uh for me sometimes it was just like hard to remember everything that I had just learned and apply it.
RE: Ok, alright. Um so for, in terms of um, problem solving problems and um uh, why do you think um. I think I already asked that question, ok um (long pause). So um, let me ask you another question. So, which type of problems help you to better understand the concepts?
PA: Uh, the actual concepts?
RE: Yeah (while the participant is talking)
PA: Probably the, the um, the problems right after the text.
RE: Ok, and ok. And for the problem solving um, what was your approach, um in terms of solving the problem before like in, in another classroom, not in my study?
PA: Ok.
RE: How was your approach?
PA: For just like concepts, or? Like I'd probably look at like uh, I always look at like what's actually being asked, like the question being asked and then finding that question in the text, skim it I think. Like and then go, and I also like read through and be like oh this looks like a problem, this looks like a problem. And then reading the actual problem, whatever's being asked,

RE: mhmm (while the participant is talking)
PA: and going back and finding it.
RE: Ok, ok, good. Ok um, let me ask you the last question. Um, what do you like or not like about the whole study? You can talk about in terms of, the, the design and or the content and.
PA: Ok, I think that um uh, I don't think it was very, very bad. I did have to think a lot during it. It wasn't like I just flew through the questions or anything like, obviously you've been here, everyone else has left (participant laughs).
RE: mhmm (while the participant is talking)
PA: But I, in a, I don't know, I think it was fine, I wouldn't, if I could give suggestion maybe for the uh text part of it, maybe breaking it up into like, you know, like highlighting, like I saw all, like whenever like criterion and construct and content were like italicized, that was easy to see.
RE: mhmm (while the participant is talking)
PA: It was good to see like those are the main points,
RE: mhmm (while the participant is talking)
PA: like so.
RE: Ok, and um, ok, besides that do you have any other things that, that you would like to see improved?
PA: Um, sometimes I think it was hard for like do you have any other suggestions, that little part, because sometimes, I was like really, I don't really know, what am I supposed to put, like so.
RE: Ok, ok.
PA: But, so maybe like if you want to answer that part or like you can, but if you don't have any other, like you don't have to because sometimes it's like I really don't have any other suggestions.
RE: Ok, alright, and maybe I, I just think of one, the other question. Um, in terms of the case study, uh last week and this week is totally different case study and um which case is more, more of the interest to you?
PA: Um, I like the, I like this week's, I think.
RE This week, the Fishman one,
PA: Yeah
RE: Ok, why do you?
PA: Um, I think uh it was really uh relevant, like it's something that we get taught like a, to, in all, in our education classes now, to do bring in all the subjects and all, everything like that. So, it was actually like a really problem that we would face. I mean they were all problems that we would face, but I think this one was easier to see, like the, to use reliability and the validity examples in it.
RE: Ok, good. Thank you.
PA: Thank you so much.

Sample Interview Transcripts

Participant: Molly
Condition: Control

Transcriptions: (RE: Researcher; PA: Participant)

RE: Ok, and um can you tell me about um what was your approach in the case study?
PA: In?
RE: For the case study, the either this week or last week.
PA: Well, I kept going, I was going back to the glossary because you could refer back your the glossary,
RE: Mhmm, mhmm (while the participant is talking)
PA: And I was seeing, you know, what validity actually was and what reliability actually was. And so I tried to apply that to the case study, being like ok, you know, this, I don't know if this is, if this has high content validity. You know, it seemed like it was a really fun activity, but like was it actually measuring that they knew all these different species, if they were just coloring their favorite color of a fish.
RE: Ok, so you tried to apply those concepts?
PA: Yeah, I tried to apply those, yeah.
RE: Ok.
PA: I don't know how well I did, but.
RE: That's good. And uh how do you think um about uh the type of mental efforts that you put in to the study?
PA: I would say that the first time I came in, it was
RE: Last week?
PA: Last, last week, I for sure had more of a mental effort because now I feel like it's spring break and I'm tired and I, you know, it's pretty outside.
RE: Uh huh (while the participant is talking)
PA: So, I feel like last week I came more focused than I did today. But, you know, mental effort, I think it wasn't too hard to understand, but you for sure had to be thinking and stuff. You couldn't just come in and click bubbles.
RE: Ok, so do you think those text message, passages are easy to read through them?
PA: Mhmm, yeah I did, I thought they were easy. I thought they were well done.
RE: Ok and you, ok so you don't have any hard time,
PA: Uh uh (while the researcher is talking)
RE: in terms of understanding,
PA: No (while the researcher is talking)
RE: the content?
PA: It was more just mixing up the words, but that wasn't the computer's fault, though.
RE: Yeah, I know, it's a lot of like,
PA: Yeah (while the researcher is talking)
RE: terminologies, you have to, you have to digest.
PA: Yeah.
RE: Yeah, ok alright um is there any other things that you like or not like about the whole, the whole,
PA: No, I think it's great.
RE: the whole instruction?
PA: I thought it was good.
RE: Ok, great. Thank you.
PA: Thank you.

Sample Data Analysis

Participant: John
Condition: Knowledge Integration

Data Analyses: John started by talking about the topic of educational measurement as a convoluted concept. A mental image is hard to capture or cover all of the information about educational measurement. He drew standardized testing in a black cloud and indicated it is an ambiguous symbol. He used raindrops as illustration of how standardized testing influences students, teachers, and school; ultimately all lead to pressure for test excellence. His concept map did not explicitly represent knowledge about reliability and validity. However, he inexplicitly implies that standardized testing is not a valid tool for assessing students' abilities. He stated that there are many other factors can influence test reliability, for example, parental expectations, self-efficacy issues, schools funding issues, etc can result in low reliability of the test. As prompted by the researcher, John defined reliability as "the ability for a student to overtime to perform the same way to, for educational measurement, to be universal and consistent with students; whereas, validity is for accurate representation of what a student can truly do." In terms of the relationship between reliability and validity, he stated that "validity helps reliability, but reliability does not necessarily need validity." He thought the standardized test has weak reliability and validity. "The reliability issues are when a child comes to the test hungry one day, and it's going to mess up his or her performance. Different factors on that day and different factors that entire week could drastically affect the outcome of a student's performance. And for validity issues, every kid knows that sometimes if you do not know the stuff you can work the best. This would screws up validity because if the child is not even trying." For the teacher-made test, he thought it has better chance of high validity but reliability might be low because it depends on the teachers. John showed fairly good understanding of what reliability and validity mean when he was prompted to provide definitions, but he seemed to have a hard time including them into his concept map.

Sample Data Analysis

Participant: Michelle
Condition: Knowledge Integration and Problem Solving

Data Analyses: Michelle started her map with standardized test as a central point and branched out to positive and negative effects with negatives outnumbering positives. Positives included outlining goals of instruction (e.g., PASS standards) and putting everyone on the same level field to assess. However, these were also the side effects of standardized testing. For example, the standardized test does not allow for creative instruction, and lacks consideration of students' backgrounds such as socioeconomic status /cultural/language. As a result, the teachers only teach to the test not to the students, and ultimately perpetuate inequality. When asked to define reliability and validity concepts, Michelle inexplicitly indicated that reliability is associated with dependability, whereas validity is associated with honesty. Michelle's was explanatory and made it easy to follow what her thought processes were. Her map included many critical issues about the standardized test, however, as the researcher prompted her to identify the concepts, she was not able to explain what the concepts meant.

Sample Data Analysis

Participant: Molly
Condition: Control

Data Analyses: The first concept map started with issues about educational measurement. Molly expressed that making the tests in the native language, modifying them when needed, and providing proper educational training are important to increase reliability and validity. When asked what reliability and validity mean, Molly could not provide good explanations but said in order for the test to be valid, it is going to hold true in other places for different students. Both reliability and validity are necessary to have a true test of whether a student understands something. She claimed the teacher made test does not necessary have higher reliability or validity than the standardized test unless teachers are really conscious of making sure the test is testing the right level and it is free of biases "and stuff like that."