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SCAFFOLDING ONLINE PEER COLLABORATION TO ENHANCE ILL-STRUCTURED PROBLEM SOLVING WITH COMPUTER-BASED COGNITIVE SUPPORT

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SCAFFOLDING ONLINE PEER COLLABORATION TO ENHANCE ILL-STRUCTURED PROBLEM SOLVING WITH COMPUTER-BASED COGNITIVE SUPPORT

A DISSERTATION APPROVED FOR THE DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

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ABSTRACT

The present study investigated the effects of question prompts and online peer collaborations on solving ill-structured problems. Sixty undergraduate students were randomly assigned to one of the four treatment groups: collaboration with question prompts, individual with question prompts, collaboration without question prompts, and individual without question prompts. Question prompts were designed to both facilitate problem solving procedure and promote students' metacognition. Students worked either individually or collaboratively with partners via MSN Messenger during the problem solving processes.

The results reveal significant effects of procedure and metacognitive question prompts in ill-structured problem solving at both overall and univariate levels. However, there was no significant effect of online peer collaboration and no significant interaction. This study supported some previous research on using question prompts as a scaffolding strategy to support problem solving. Further, these findings support a redefined IDEAL problem solving model for solving ill-structured problems. The findings suggest many implications for instructional designers, educators in web-based learning environments, and educational researchers. These implications and the limitations of this study are discussed.

CHAPTER ONE

INTRODUCTION

Background of the Study

Web-based instruction has been gaining use in educational settings during the past several years and has brought many benefits to education. However, without face-to-face guidance, monitoring, and communication from the instructor or with peers, students in web-based learning environments may experience difficulties, especially for learning tasks such as problem solving, which aim to develop higher-order thinking skills.

Two promising strategies for providing scaffolding for student problem solving are computer-mediated peer collaboration and question prompts (Cheung & Hew, 2004; Ge & Land, 2003; Uribe, Klein, & Sullivan, 2003). In computer-mediated peer collaboration, appropriate moderation and guidance are critical for successful learning (Bernard, Rojo de Rubalcava, & St-Pierre, 2000; Xie, DeBacker, & Ferguson, 2006; Zhang, 2004).

However, in large collaboration situations, such as when multiple collaborative groups interact at the same time, moderation or guidance normally provided by instructors or trained students might not be available for all groups. Therefore, alternative ways of providing guidance need to be considered. Research studies indicate that appropriately programmed computers can function as cognitive partners for learners by providing scaffolding or supportive question prompts during the learning processes (Salomon, 1987; Zellermayer, Salomon, Globerson, Givon, 1991).

Although studies have addressed various aspects of online collaboration and question prompts in problem-solving, the validity of these studies still needs to be strengthened by applying these scaffolding strategies in different subject domains and with different research samples. Moreover, little research has addressed the interaction of online peer collaboration and question prompts in solving ill-structured problems to understand the effects of these scaffolding strategies for different problem solving components.

Variables to be Investigated

The independent variables in this study include treatment condition (online peer collaboration and question prompts). The dependent variable is problem solving performance, which involves all the components of problem solving – number of problems identified, problem description, problem identification, justification for problem representation, number of solutions, quality of solution, rationale for solution, and solution consequence anticipation.

Purpose of the Study

The purpose of this study is to investigate the effect that computer-mediated peer collaboration and question prompts have in the process of solving ill-structured problems. This study also investigates whether question prompts can effectively moderate peer collaboration during an ill-structured problem solving task.

This study was designed under the theoretical framework of Vygotsky's social development theory, which asserts that learning should be matched with the student's development level. Vygotsky's zone of proximal development refers to "the distance 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." He believed that scaffolding can promote student learning within the zone of proximal development (Vygotsky, 1978). Therefore, the present study hypothesized that by interacting with peers through online collaboration, students will perform better in problem solving. The present study also hypothesized that students will perform better in problem solving when question prompts are provided. Question prompts not only provided structure and guidance for peer collaboration, but also offered procedural facilitation that allows students to perform like experts and metacognitive facilitation that promotes higher-order thinking. In this study, peer collaboration and/or question prompts were provided to support students engaged in solving ill-structured problems in an online learning environment. Online collaboration was supported via the latest version of an instant messaging tool, MSN Messenger, which provided synchronous computer-mediated communication between peers. Question prompts were designed to provide both procedural and metacognitive facilitation under the framework of an IDEAL problem solving model that was described by Bransford (1993) and that is redefined in a later section in this paper.

The findings of this study provide empirical evidence for the effectiveness of online collaboration and question prompts in the process of problem-solving. This study provides a better understanding of the nature and process of solving ill-structured problems.

CHAPTER TWO

LITERATURE REVIEW

The Nature of Problem-Solving

Problem-solving involves various cognitive activities and requires deep cognitive processing (Anderson, 2000). It is commonly viewed as one of the most complex cognitive skills that people use in everyday life (Chi & Glaser, 1985). Gagné identified a hierarchy of different types of learning outcomes wherein problem-solving is at the highest level among intellectual skills (Gagné, Briggs, & Wager, 1992). In formal education settings, more and more attention has been paid to developing students' problem-solving skills and supporting students to use appropriate processes and principles for making decisions in authentic problem-solving activities. Therefore, understanding the nature and the process of problem-solving and exploring effective strategies and learning environments to support students in solving problems are critical issues for instructional designers, educators, and educational researchers.

According to Information-Processing Theory, a problem contains an initial stage and a goal stage. The problem-solving process tries to identify the initial stage and construct a representation of the problem according to existing knowledge (Gick, 1986), then search for solutions to bridge the gap between the initial stage and the goal stage by performing some operations under some specific rules or constraints (Chi & Glaser, 1985; Greeno, 1978; Simon, 1978). Different types of problems are categorized as well-structured problems or ill-structured problems based on their attributes and the basic components of problem-solving processes (Chi & Glaser, 1985; Chi, Glaser, & Farr, 1988; Johnson, 1988; Jonassen, 1997; Simon, 1978; Sinnott, 1989b; Voss & Post, 1988).

Well-structured problems involve all components of the problem, including a well-defined initial stage, a known goal stage, and a constrained set of logical operators (Greeno, 1978). Well-structured problems have two different types: puzzle problems and domain specific problems. *Puzzle problems* are domain-independent problems (Jonassen, 1997), with a single correct answer where all elements required for the solution are known and solutions require using logical and algorithmic processes (Kitchner, 1983). This type of problem normally is decontextualized and abstracted from complex real world situations and does not contain domain specific knowledge (Chi & Glaser, 1985). The Tower of Hanoi, the Nine Dots problems, and Cannibal problems all are examples of puzzle problems designed to manifest certain aspects of thinking and reasoning processes, or human intelligence (Jonassen, 1997; Simon, 1976). *Domain knowledge problems* are constrained domain-specific problems with single solutions, optimal solution paths, and structured goals (Chi & Glaser, 1985; Jonassen, 1997; Sinnott, 1989a). A distinct difference between puzzles and domain knowledge problems is that a fair amount of knowledge of a specific area is necessary for the solution of the domain knowledge problems (Chi & Glaser, 1985).

Well-structured problems are commonly used in school settings, because the problem-solving process and patterns are clear and straightforward and other distractive aspects are designed to be excluded. Consequently, learners can clearly perceive the underlying principles or rules while solving well-structured problems. Many problems in textbooks are well-structured domain knowledge problems. They require “the application of a finite number of concepts, rules, and principles being studied to a constrained problem situation” (Jonassen, 1997). By applying the concepts, rules, and principles in solving well-structured problems, problem solvers actually practice the knowledge that they learn from text, build experiences and schema in solving problems, and then apply their problem-solving knowledge to analogical problems. However, in contrast to the complex nature of real world problems, the simplicity of well-structured puzzle and domain knowledge problems also brings limitations to the application and transfer of such problem-solving skills for authentic situations. Learners may not be able to solve complicated real world problems if they only have knowledge and skills in solving well-structured problems.

Ill-structured problems are situated in authentic everyday practice. They seem to be more common in human experience than well-structured problems, and are much more interesting and meaningful for learning (Jonassen, 1997; Sinnott, 1989b). In an ill-structured problem, one or all of the three components of problems (initial stage, a set of permissible operators, and a goal stage) may not be well specified in the problem statement (Chi & Glaser, 1985). Thus, it is less obvious what actions are needed in order to solve it (Gerjets, Scheiter, & Catrambone, 2004). Ill-structured problems may possess multiple solutions and solution paths, or none at all, with the appropriateness of the solution dependent upon the rationale for the solution (Johnson, Johnson, & Smith, 1991). They also may be unclear with regard to the concepts, rules, and principles required for solving the problems (Jonassen, 2000). Therefore, solving ill-structured problems requires domain specific knowledge, such as propositional information, concepts, rules, and principles, which allows problem solvers to specify problem components and consequently supports solution generation (Ge & Land, 2004). More cognitive effort is needed in solving ill-structured problems compared to well-structured problems.

Examples of ill-structured problems include instructional design problems, programming problems, project management problems, and so forth.

However, well-structured and ill-structured problems do not constitute a dichotomy but instead represent points on a continuum (Reitman, 1965). Voss and Post believed that for an expert a problem may be relatively well-structured but for a novice the same problem may be quite ill-structured because they have different level of expertise and experience in problem-solving so that they have different problem representations and see different patterns of the problems (Voss & Post, 1988). In addition, Simon (1973) stressed that problems that are initially ill-structured become well-structured during the problem-solving process.

Well-Structured Problem-solving Process

Many researchers have conducted studies on well-structured problem-solving and developed theories and models to explain the problem-solving process. Bransford (1993) presented a problem-solving model, IDEAL, based on Information-Processing Theory (Newell & Simon, 1972; Simon, 1978). Although this model was targeted to explain the general problem-solving process, it best captures the simple, clear, and well-defined nature of well-structured problems. It can be used to explain well-structured problem-solving process. The IDEAL approach presents the problem-solving process under an IDEAL framework – Identify problems and opportunities, Define goals, Explore all possible strategies, Anticipate outcomes and Act, and Look back and Learn. This model involves five components that work together organically for solving the problem (Bransford & Stein, 1993). Furthermore, it is important to note that the problem-solving process should involve these five components flexibly to achieve a satisfactory situation; the flexible process of problem-solving does not have to be in a fixed IDEAL order. Gick (1986) added to the IDEAL model by pointing out that problem solvers will jump from the problem representation stage to the action stage when their schema related to similar situations is activated (Chi & Glaser, 1985; Gick, 1986; Greeno, 1978; Rumelhart, 1981). A schema is defined as an organized body of knowledge in memory (Chi & Glaser, 1985). It is a cluster of knowledge related to a problem type and contains information about the typical problem goal, constraints, and solution procedures useful for that type of problem (Gick, 1986). In the schema-driven situation, the problem solvers are able to proceed directly to the solution implementation stage and try out the activated solution depending on the problem representation and their schemata (Hayes, 1987; Newell & Simon, 1972). The process for solving well-structured problems can be demonstrated in Figure 1.

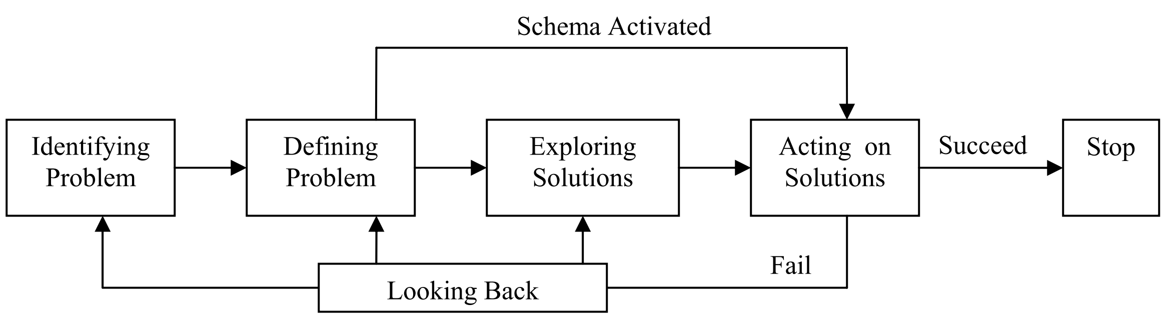

Figure 1. IDEAL model for well-structured problem-solving (Adapted and Modified from Gick, 1986)

Ill-Structured Problem-solving Process

The IDEAL model is a general method of solving problems effectively, representing the process for solving well-structured problems. However, in the context of ill-structured problem-solving, the IDEAL model seems inexplicit and insufficient to explain the problem-solving processes because ill-structured problems are much more complicated and ill-defined. Although the process of solving ill-structured problems is still based on the general problem-solving model, more cognitive efforts need to be put into specifying or adding information to clarify the ill-defined problem components, such as initial stage, goal stage, optional solution path, and so on. Later justifications need to be provided to support the clarification processes and the solution path, as well as monitoring and evaluating the solutions for problem situations. Simon (1973) proposed that ill-structured problems require “a relatively large amount of problem-related information stored in long term memory and/or external memory,” thus the process used to solve ill-structured problems involves “specifying the information especially germane to the solution, thus reducing the ill-structured problem to a well-structured problem (or a set of well-structured problems)” (Simon, 1973; Voss & Post, 1988). In other words, because ill-structured problems contain vague and unclear components with interrelated distracting information, the solvers of ill-structured problems must have appropriate conceptual knowledge of the problem components as well as knowledge of how to utilize the appropriate components, sort out available information, and add new information to reduce the ill-definedness of the problems and make them solvable.

A model of the components in solving ill-structured problems was created by Sinnott using a thinking-aloud approach. This model contains five components of a problem-solving process: (1) processes to construct problem spaces; (2) processes to choose and generate solutions; (3) monitors; (4) memories; and (5) noncognitive elements (Sinnott, 1989b). She argued that ill-structured everyday problems may have a large problem space or multiple problem spaces available for solvers. During the problem-solving process, the solver assesses his or her desired number of spaces according to his or her experience or pre-knowledge with the problem. When the essence of a problem is selected, then the goal or goals must be selected, and finally a solution or solutions must be generated and selected. During the selection process for the "essence" and solutions of problem, the solver needs to have a mechanism for choosing the best goal and solution (Sinnott, 1989b). Sinnott also emphasized the importance of the monitoring process in problem-solving and believed that the monitoring process sometimes helped problem solvers stay on track and deal with their limitations, and also let them decide about the nature of the problem and the goal to choose.

Other researchers also address ill-structured problem-solving process and agree that solving ill-structured problems should emphasize (1) problem representation, (2) generating and selecting solutions, (3) making justifications, and (4) monitoring and evaluating goals and solutions (Ge & Land, 2003; Gerjets, Scheiter, & Catrambone, 2004; Voss & Post, 1988; Voss, Wolfe, Lawrence, & Engle, 1991).

Moreover, researchers suggested that the information for specifying the problem components and exploring potential solutions could come from the perception of a problem-solver community (Reitman, 1965; Voss & Post, 1988). A community of practice is a group “of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis” (Wenger, McDermott, & Snyder, 2002). Reitman stressed the importance of community influence in identifying ill-structured versus well-structured problems in the problem representation process (Reitman, 1965). Voss built on Reitman’s discussion and used the notion of community (referred as pragmatic criterion) to discuss the solution for ill-structured problems (Voss & Post, 1988). He posits that a solution is regarded as good if other solvers find little wrong with it and think it will work, whereas a solution is regarded as poor if other solvers are able to show why it will not work. Moreover, in a general sense and perhaps quite importantly, it means that solution quality will be based upon the extent to which a solution can be rationalized. The community provides the criterion for problem representation and solution evaluation. It also provides cues and feedback to problem solvers, which will influence the decision making for the whole problem-solving processes.

Consistent with this discussion of ill-structured problem characteristics and the problem-solving components of ill-structured situations, here the present study proposes a redefined version of the IDEAL model (see in Figure 2) for problem-solving processes in the context of ill-structured problems.

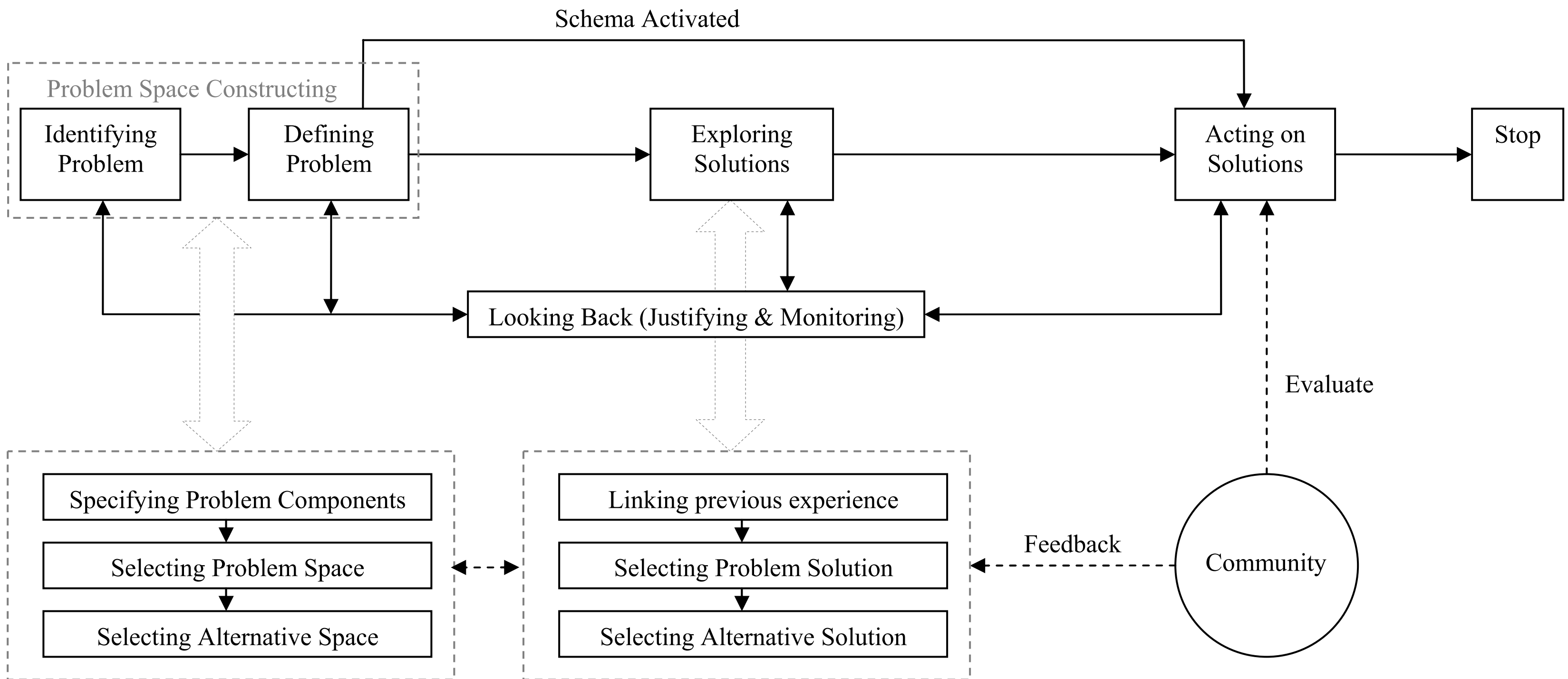

Figure 2. A Redefined IDEAL Model for Ill-Structured Problem-solving Processes

In this model, four major differences are introduced in contrast to the general problem-solving model.

First, a deeper analysis is needed in the problem representation stage. To identify and define a problem, additional information needs to be sought. After identifying the problem components, problem space will be specified. In addition to a primary problem space, alternative spaces also will be selected. This analysis allows problem solvers to select or adjoin critical information needed and exclude superfluous distractions from the complicated problem situation so as to gain a clear representation of the ill-structured problems. Much cognitive effort needs to be made in this process, such as retrieving concepts, rules, and principles in specific domains, connecting this knowledge with the problems, and recalling previous experiences in similar situations. Once problem spaces have been selected, the representation of the problem is more specified supporting schema activation or solution exploration in a sensible manner. Problem solvers may use many strategies to support their problem space construction for ill-structured problems. Commonly used strategic tools are concept map, domain knowledge base, search engine, worked examples in similar situations, statistical data representation tools, and so forth.

Second, problem solution exploration involves different paths for primary solutions and alternative solutions. Since ill-structured problems do not have a single correct solution and solution path, the problem solution exploration might be more complex than is the case with well-structured problems. In this process, the problem solvers might brainstorm solutions and try out different strategies to solve the problem. Moreover, due to the uncertainty of problem representation, the problem solvers might choose primary solutions and alternative solutions for the different problem spaces they select. The diversity of the solution paths depends on the differences among solvers' problem-solving expertise and the differences in problem representations. Novices tend to generate solutions focusing on superficial problems whereas experts generate solutions addressing the essential problems below the surface (Bransford, Brown, & Cocking, 1999; Chi, Glaser, & Farr, 1988).

Third, the looking back process works differently in ill-structured problem-solving processes. Since ill-structured problems have no single solution path, problem solvers must constantly monitor and justify their cognitive actions. Therefore the looking back process is applied through all the problem-solving processes, which requires metacognitive and self-regulation skills, whereas in the general problem-solving model the looking back process only must be used when the solution fails or for the purpose of evaluation and learning. Constant monitoring enables solvers to examine problem-solving processes and movements from one stage to another and to know the limits of knowing, the criteria for knowing, and the certainty of knowledge (Gerjets, Scheiter, & Catrambone, 2004; Sinnott, 1989b). Justifications through the whole process provide logic and rationale for all the reasoning and decision-making in the ill-structured problem-solving processes.

Finally, the notion of community is important in the refined IDEAL model for ill-structured problems. Although the community of problem solvers is not a component of the problem-solving process in the IDEAL model, it is included in this redefined model because it has critical influences on and plays an important role in the reasoning and decision making in the problem-solving process. The community suggests evaluation criteria to solutions and provides feedback to the problem representation process.

Scaffoldings in Instruction

Over the years, many studies have been conducted aiming to support students' learning and their knowledge development (Palincsar & Brown, 1984; Scardamalia, Bereiter, & Steinbach, 1984). In these studies, scaffoldings play an important role in learning and development. Scaffolding refers to a "process that enables a child or novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts" (Wood, Bruner, & Ross, 1976). They are "forms of support provided by the teacher (or another student) to help students to bridge the gap between their current abilities and the intended goals" (Rosenshine & Meister, 1992).

Zone of Proximal Development

The notion of scaffolded instruction was introduced in Vygotsky's Social Development Thoery (Vygotsky, 1978), which held that learning and development are interrelated in students' everyday life. Learning should be matched in some manner with the students' development level. The relationship between learning and development was explained in terms of the zone of proximal development (ZPD), which refers to "the distance 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). The aim for scaffoldings is to bridge this gap. He also pointed out that scaffoldings should be provided only within the ZPD. Learning activities that are oriented toward development levels that already have been reached are ineffective and learning activities that are oriented toward developmental levels that are too far advanced for the learners' potential ability are also not effective. When the learner interacts with an adult or a more skilled peer within the ZPD, he or she is guided and supported to a greater competence and becomes capable of performing at a higher cognitive level independently once the guidance and supports are internalized (Hogan & Tudge, 1999). The scaffolding internalization process enables learners to achieve the tasks without guidance and supports from social interaction. This is a critical process for students' development.

Vygotsky's ZPD has functioned as the basic theoretical framework for many studies related to scaffolding in educational settings (Davis & Linn, 2000; Ge & Land, 2003; King, 1991a; Lin & Lehman, 1999; Palincsar, 1986; Palincsar & Brown, 1984; Salomon, 1987; Scardamalia & Bereiter, 1985; Scardamalia, Bereiter, & Steinbach, 1984; Zellermayer, Salomon, Globerson, & Givon, 1991). These studies investigated the effectiveness of different scaffolding strategies, including reciprocal teaching, modeling, questioning, cooperative learning and peer interaction, utilized in different subject domains, such as reading, writing, and science learning.

Strategies for Scaffolding

Reciprocal Teaching

Palincsar and Brown (1984) used a strategy called reciprocal teaching to provide scaffolding for students in reading comprehension. Reciprocal teaching in a reading context could refer to having the "teacher and students take turns learning a dialogue concerning sections of a text. In addition to reciprocal questioning, the teacher and students take turns generating summaries and predictions and in clarifying misleading or complex sections of text" (Palincsar & Brown, 1984). In reciprocal teaching, the teachers initially provide explanation coupled with modeling, then fade out the modeling and function more in the role of coach providing corrective feedback and encouragement, promoting self-evaluation, and reintroducing explanation and modeling as appropriate (Palincsar, 1986).

Palincsar and her colleagues investigated the effects of reciprocal teaching intervention in elementary reading classes (Palincsar & Brown, 1984). In their intervention, student groups were formed and led the discussions in their classes as student teachers. The instructor provided guidance necessary for the student teachers to complete class activities. The guidance involved prompting, instruction, and modifying the activities. The instructor also provided praise and feedback to students' participation. The study found that the reciprocal teaching method could lead to success in reading comprehension activities, which involve summarizing (self-review), questioning, clarifying, and predicting. In the study, the reciprocal process involved extensive modeling of comprehension-fostering and comprehension-monitoring activities. With guidance and feedback from the teacher and student peers, the reciprocal teaching routine forces the students to respond, even if the level of which they are capable is not yet that of an expert. These processes provide opportunities for student internalization and increased capability in performing tasks.

Modeling

In reciprocal teaching, modeling has been used as a strategy to initiate the learning processes. Modeling provides examples of the required performances, whereby the most important steps and decisions are stressed. The goal of modeling is imitation of the performance of an expert by the learner.

Scardamalia et al. (1984) used modeling strategy along with procedural facilitation and strategic training to help student writing (Scardamalia, Bereiter, & Steinbach, 1984). In their study, modeling was used both with the instructor as model and with students modeling. This study found that modeling was effective in promoting the use of expert-like reading comprehension and writing strategies.

Bielaczyc and her colleagues used modeling to provide metacognitive supports for college students to learn computer programming (Bielaczyc, Pirolli, & Brown, 1995). They used video technology to provide explicit modeling of metacognitive strategies and training in their use. They found that when students compared their own performance with that of the model, and take action to revise ineffective learning approaches, the learning models were very effective. Salomon used a computer tool, the Reading Partner, to provide modeling for student reading and found that it was helpful to lead students to performance more like an expert (Salomon, 1987).

The literature supports the use of modeling in instruction as an effective strategy for scaffolding (Scardamalia, Bereiter, & Steinbach, 1984). It provides examples, models, and templates for novices to follow, imitate, and then internalize as their own knowledge in their learning and development.

Questioning

Many researchers suggest prompting students with appropriate questions is an effective strategy for scaffolding. Studies indicate that among the four strategies in reciprocal teaching, questioning played the most dominant role in teachers' practice (Hacker & Tenent, 2002; Rosenshine & Meister, 1994).

By asking questions, teachers can guide students to act in tasks in a more expert-like manner, to make self-justifications, self-explanations, and self-evaluations, and acquire a better understanding of the kinds of questions they should be addressing in learning and problem-solving practice. The process of scaffolding in the form of questioning provided by the teacher can help students gain the knowledge and skills necessary for managing their own learning, as well as their problem-solving performance.

King and her colleagues conducted a series of studies investigating the effects of a questioning strategy on learning. King (1991) used strategic questions to a guide students' cognitive and metacognitive activity during problem solving. Students worked in pairs to solve computer-assisted well-structured problems. The treatment group received guided question card that was used as a question prompt during problem solving. Examples of the guided questions include "What are we trying to do here?", "What do we know about the problem so far?", "What is our plan?", and "Is there another way to do this?" The study found that the questioning strategy promoted problem-solving success by teaching students how to be strategic problem solvers. King (1991b) also investigated the effects of a self-questioning strategy for reading comprehension. An example of the self-question prompts is "What do I still not understand about this?" She found that use of a self-questioning strategy can improve high school students' comprehension of lectures. Moreover, students can maintain this strategy when external prompts are removed. Later, she conducted a study on guided strategic peer questioning strategy for science classes (King & Rosenshine, 1993). She compared not only guided peer questioning with unguided peer questioning, but also elaborated guidance for peer questioning with unelaborated guidance. The elaborated questions are very structured such as "Why is…important?" and "What would happen if …?" The unelaborated questions are more like signal words such as why, what, and how. These questions were used to guide students to generate questions and ask each other. She found that children with elaborated guiding questions outperformed those with less elaborated guiding questions on explanation, comprehension, and knowledge mapping.

Salomon (1987) believed that a computer tool, Reading Partner, that provided explicit regulatory, metacognitive-like guides that could be internalized by learners could improve learners' performance and leave a transferable cognitive residue in the form of improved competencies, by serving as a "more capable peer" in learners' zone of proximal development. Following this line, Zellermayer, Salomon, and their fellows (1991) believed that ongoing computerized procedural facilitation with strategies and writing-related metacognitions during writing improves learners' writing while they are being helped, as well as leaves a cognitive residue in the form of subsequently improved writing, once that help is removed (Zellermayer, Salomon, Globerson, & Givon, 1991). They investigated the effects of a computer tool, Writing Partner, in students' writing process. Writing Partner was designed to provide support to students during writing by way of prompting students with questions via the computerized learning environment. The question supports included memory supports (e.g. "What is the topic of your composition?"), metacognitive-like guidance (e.g. "Do you want your composition to persuade or to describe?" and "What kind of audience are you addressing?"), and higher-order thinking supports (e.g. "Where are some of your main points?" and "What are some key words that come up in your mind while thinking about this topic?"). The study revealed that significant improvements in writing quality could be attributed to the explicit and unsolicited guidance provided by the Writing Partner.

The major goal for questioning is to provide a means to externalize mental activities that are usually covert (Scardamalia & Bereiter, 1985). The question prompts can be either more procedural guidance or more towards fostering metacognitive-like support.

Procedural prompts are designed to help learners complete specific tasks. They provide learners with specific procedure hints or suggestions that facilitate the completion of the task. Learners can temporarily rely on these prompts until they construct their own internal structures for completing the tasks (Scardamalia & Bereiter, 1985). These procedural facilitations include "turning normally covert processes into overt processes; reducing potentially infinite sets of choices to limited, developmentally appropriate sets; providing aids to memory; and structuring procedures so as to make it easier to escape from habitual patterns" (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). Studies showed that procedural prompts could facilitate learners' understanding of domain knowledge by activating prior knowledge and elaborating their thinking process (King, 1991a, 1991b, 1992, 1994). They could help students finish activities and lessen the cognitive load on students by reminding them how to accomplish the activity (Davis, 1996; Davis & Linn, 2000; Zellermayer, Salomon, Globerson, & Givon, 1991). They also would offer guided stimulation of higher-order processes of planning, transcribing, diagnosing, and revising, which novices are not likely to activate on their own (Zellermayer, Salomon, Globerson, & Givon, 1991). Procedural prompts have been used successfully to help students learn cognitive strategies in different areas such as reading, writing (Englert & Raphael, 1989; Scardamalia, Bereiter, & Steinbach, 1984), and domains of information science and technology (Ge & Land, 2003).

Metacognitive prompts, on the other hand, can provide one method for fostering self-monitoring, self-explaining, and self-evaluation and knowledge integration. Prompting students to explain or justify has been shown to improve learning in subjects such as reading (Palincsar, 1986; Palincsar & Brown, 1984; Salomon, 1987), writing (Salomon, 1993; Zellermayer, Salomon, Globerson, & Givon, 1991), and science learning (Davis & Linn, 2000; Lin & Lehman, 1999). Research shows that students who are required to periodically stop during problem-solving and ask themselves metacognitive or reflective questions are more likely to focus on the process of problem-solving and have better performance in problem-solving (Schoenfeld, 1985). Prompting students with metacognitive questions also can foster problem-solving knowledge transfer (King, 1991a; Lin, 2001; Zellermayer, Salomon, Globerson, & Givon, 1991). Zellermayer (1991) believed that externally provided metacognitive-like guidance during writing would be expected not only to improve writing while it is provided, but also to become internalized to serve as self-generated self-regulation during unaided writing. Helping students develop abilities to monitor and revise their own strategies and uses of resources may enable them to improve general learning expertise that can be used in a wide variety of settings (Scardamalia & Bereiter, 1985). By monitoring effectiveness of one's own learning and uses of resources, students may be able to see the need to pursue a new level of learning and understanding (Lin & Lehman, 1999).

Other ways for prompting that have been encouraged are through students' self-questioning (King, 1992; Rosenshine, Meister, & Chapman, 1996) or peer-questioning (Choi, Land, & Turgeon, 2005; Ge & Land, 2003; King, 1991a). Students who are engaged in group problem-solving could be trained to ask appropriate questions to themselves or of their peers, the quality of their discussion about the problem might be enhanced and their metacognition might be facilitated, resulting in increased learning.

Collaborative Learning and Peer Interaction

Vygotsky's social development theory emphasized the interaction between peers in student learning and development. Collaborative learning is an educational approach that involves joint intellectual effort by student peers or students and teachers together. In collaborative learning, students work in groups and interact with peers, mutually searching for understanding, solutions, or meanings, or creating a product.

Many studies found that collaboration improves performance on complex or higher-order thinking activities. Learners appeared to benefit from the ability to discuss the problem, brainstorm potential solutions, and arrive at a final solution (Johnson, 1988; Mergendoller, Bellisimo, & Maxwell, 2000). King (1991) found that the cognitive benefits of peer interaction for individuals would undoubtedly improve the problem-solving performance of a collaborating pair. Partners trained to use this guided peer-questioning and responding strategy were expected to be more successful in solving problems than those in an untrained control group (King, 1991a).

McInerney et al. examined the comparative effects of metacognitive strategy training within a cooperative group learning context and a traditional direct instruction approach. They found that the cooperative instructional approach, compared to direct instruction approach, could maximize positive cognitions and achievement in a compulsory computer training situation while minimizing student anxiety (McInerney, McInerney, & Marsh, 1997).

Ge and Land (2003) examined the effects of question prompts and peer interactions in scaffolding undergraduate students to solve ill-structured problems. Although the quantitative data did show significance on peer interactions, their qualitative findings indicated that under appropriate guidance and monitoring, peer interaction has positive effects in facilitating cognitive thinking and metacognitive skills for students to solve ill-structured problems (Ge & Land, 2003). Later, they summarized previous studies and pointed out that peer interaction may be advantageous in a number of ways, particularly in providing and receiving explanations, co-constructing ideas, resolving conflicts, and negotiating meaning (Ge & Land, 2004).

Most recently, Fawcett and Garton (2005) investigated the effects that collaborative learning has on children's problem-solving ability. They compared students' problem solving performance in a card sorting activity under two different conditions (individual versus peer collaboration). They found students perform significantly better when they collaborated. They also found that only those children of low sorting ability who collaborated with higher sorting ability peers showed a significant improvement in post-test versus pre-test. In addition, they found that only those students who were required to explain the sorting activity had significance in post-test versus pre-test (Fawcett & Garton, 2005).

In collaborative learning, students actually benefit from receiving and giving explanations and suggestions. Webb and Farivar suggested that receiving explanations can benefit students when the explanations are elaborated and are actively used to solve problems. They also believed that the benefits of giving explanations involve cognitive restructuring, which helps to understand one's own perspectives, and not just cognitive rehearsal (Webb & Farivar, 1999).

Greene and Land (2000) did a qualitative analysis of college students using different types of scaffolding in a web-based learning environment. They found that student-student and student-teacher interaction was useful in influencing the development of ideas "when group members offered suggestions, when they were open to negotiation of ideas and sites to access, and when they shared prior experiences" (Greene & Land, 2000).

Therefore, in addition to passively listening to an explanation, learners need to construct meanings with peers and to negotiate the inconsistencies of conflicting views. The conversations between peers on controversial ideas make cognitive conflicts overt, and then through negotiation students can gain better understanding during peer collaboration.

Many studies examined strategies to support peer collaboration including guided peer-questioning (King, 1991a, 1992, 1999) and reciprocal teaching (Hacker & Tenent, 2002; Palincsar & Brown, 1984) in face-to-face peer collaboration practice. They found these strategies help students to generate more critical thinking and fewer low-level elaborations in the course of collaboration. Another approach to investigating peer collaboration support is to study the effectiveness of technology support for peer collaboration in the form of computer-mediated peer collaboration. The following sections will review studies on computer mediated peer collaboration.

Computer Mediated Communication

With computer technology and Internet use spreading rapidly throughout the world, many instructions have been moved and integrated into computer or web supported environments. These environments can provide students with multimedia information presentation, interaction and communication, and self-paced learning.

Nature of Computer-Mediated Communication

Computer-Mediated Communication (CMC) allows anytime/anyplace use through computer networks (Barnes & Greller, 1994; Romiszowski & Maso, 1996). Increasingly, CMC is being integrated into not only distance learning classes, but also on-site educational settings to extend learning activities beyond the traditional classroom (Xie, DeBacker, & Ferguson, 2006). CMC has the potential to facilitate learning communities and to promote collaborative learning among students in and outside of classrooms (Duemer et al., 2002; Horton, 2000; Murphy, 2004).

CMC provides two different types of communication: synchronous and asynchronous communication. Synchronous communication allows two or more people from different locations to communicate in real time, such as instant messaging and teleconferencing. These tools have the advantage of being able to engage communication instantly and at the same point in time. They support real-time collaboration, such as for brainstorming and generating feedback or solutions. Asynchronous communication links participants separated by time and space to construct learning knowledge, such as discussion board and email lists. These tools allow people to communicate with each other at each person's own convenience and own schedule. Asynchronous tools are useful for sustaining dialogue and collaboration over a period of time. Both types of CMC have many advantages to support interpersonal interaction in learning environments. First, CMC provides anytime/anyplace communication for students and teachers, which breaks the limits of time or space and provides more opportunities and more convenience for students and teachers to communicate with each other. Furthermore, CMC offers more equal opportunity for students to participate in the discussion regardless of their oral language skills and personality (Zhang & Mu, 2003). Researchers also found that students would use lexically and syntactically more formal and sophisticated language in electronic discussion than they would do in face-to-face discussion (Warschauer, 1996). In addition, online discussion systems provide digital text records capturing the history of the interactions of a group, allowing for collective knowledge to be more easily shared and distributed.

Some empirical studies in the literature indicate CMC can have positive effects for collaborative learning during problem-solving. For example, Uribe et al. (2003) used synchronous computer-mediated collaboration on ill-structured problem-solving tasks. Fifty-nine students were asked to work on ill-structured problems individually or collaboratively via CMC. The study found participants in CMC performed significantly better than did participants working alone in terms of quality and time (Uribe, Klein, & Sullivan, 2003). Cheung & Hew (2004) analyzed the content of an online discussion and reflective log and found the use of asynchronous online discussion in an Asian context had positive effects on problem space articulation and solution generation in ill-structured problem-solving process (Cheung & Hew, 2004).

Moderation in CMC

A successful online collaboration should be well facilitated and guided so that students can feel the collaboration is not only informational, but also interesting (Flannery, 1994). The importance of guidance in peer collaborative learning has been recognized in practice and research.

Xie et al. (2006) investigated online collaboration from a motivational perspective. Both students' and instructors' interviews suggested that instructor's moderation or guidance played an important role for students' motivation to participate in online collaboration. With instructor guidance, students perceived that online activity was a useful and valuable way to communicate and get information. Their intrinsic motivation was promoted and they showed more willingness to continue to participate in this type of discussion (Xie, DeBacker, & Ferguson, 2006).

Zhang and Peck (2003) found that structuring and moderating efforts on group work and the collaboration process in online forums led to stronger reasoning in a group problem-solving task in self-selected group in a traditional college. Groups that had received external structuring and moderation performed significantly better in both well-structured and ill-structured problem-solving tasks (Zhang & Peck, 2003).

In a moderated discussion group the instructor or someone else watches over the exchange of messages. This moderator may start or participate in discussions, provide timely feedback to difficult questions, identify the key issues remaining to be addressed, or make explicit suggestions for further development (Benfield, 2002; Horton, 2000). A good moderator also has to both stand back and let the participants play the main role in the discussion and also intervene to guide the discussion into useful directions. Bernard et al. (2000) also suggested that instructors assume a facilitator's role in an online collaborative learning environment (Bernard, Rojo de Rubalcava, & St-Pierre, 2000).

Computer Supported Peer Collaboration

Computer-Mediated Communication extends the effectiveness of peer collaboration as a scaffolding method for learning beyond face-to-face settings. Given the lack of face-to-face guidance and control over the collaboration process, a moderator plays an important role in an effective CMC collaboration. The instructor or a trained student is commonly viewed as an ideal person to monitor the collaboration activity, provide feedback to students, and direct the interactions to the desired channel. However, in reality, when several collaborative groups are working on instructional tasks during the same time period, especially in a synchronous mode, it is difficult for one instructor or a few trained students to moderate all these groups. Therefore, researchers have been trying to explore alternative approaches for CMC moderation. Integrating technology in CMC environments to provide scaffoldings for peer collaborations might have positive potential.

Computer as Partner

Computers can serve as cognitive tools that can help the development of thinking skills (Salomon, 1987). These tools can provide "model construction, simulations, or other exploratory activities which can afford an intellectual partnership with learners," and also provide explicit humanlike guidance that could be "internalized and thus leave transferable cognitive residue" (Salomon, 1987).

Salomon's study (1987) found intellectual partnership with a computer tool, Reading Partner, which provides reading-related, metacognitive-like guidance, leads to the internalization of the guidance. Zellermayer et al. (1991) found a computerized Writing Partner can help students gradually move from knowledge-telling to knowledge-transforming by providing them question prompts during writing (Zellermayer, Salomon, Globerson, & Givon, 1991). Davis and Linn (2000) used the Knowledge Integration Environment (KIE), which was developed based on computerized learning partners, to provide prompts or cues to help students solve science problems. KIE was supported to be a successful computer partner of students during problem-solving. Mayer et al. (2003) designed an on-screen agent as a multimedia computer partner to provide students guidance and feedback using words, illustrations, and animation. They found students performed better on a problem-solving transfer test when the on-screen agent's explanation was provided via multimedia and when students were able to ask questions to and receive answers from the computerized partner interactively (Mayer, Dow, & Mayer, 2003). Both Lin's (1998) and Ge and Land's (2003) studies supported the assertion that computerized cognitive partners have positive effects on students' problem-solving by providing question prompts (Ge & Land, 2003; Lin & Lehman, 1999). The literature suggests that a computer tool can serve as a "more capable peer" in a learner's zone of proximal development and can thus facilitate the development of competency (Salomon, 1993).

Computer Supported Peer Collaboration

Katz and Lesgold (1993) summarized three main roles of a moderator in collaborative learning activities: (1) Provide advice on demand; (2) Provide quality control over peer critiquing and other collaborative activities; and (3) Manage collaborative activities. They believe that a computer system can serve these roles in collaborative learning activities. Following this assumption, they proposed a computer tutoring system for collaborative learning, Sherlock II that integrated artificial intelligence technology in the learning environment (Katz & Lesgold, 1993). The system not only prompts students with suggestions, but also analyzes students' discussion content automatically to control the peer interaction. However, this system was still in prototype when they published later paper on this project in 2000 (Katz, Aronis, & Creitz, 2000). Other projects also attempted to use artificial intelligence to support online collaborative learning such as MEMOLAB (Dillenbourg, Mendelsohn, & Schneider, 1994) and Three's Company (Lin, 1993). These systems emphasized the sophisticated techniques and the interface design to analyze the communication, control peer interaction, and manage the discussion process.

However, Scardamalia et al. argued that these systems are not only difficult to realize with high investment of time, cost, and human efforts, they also may be heading in the wrong direction (Scardamalia, Bereiter, & Lamon, 1994; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). They proposed another approach for supporting collaborative learning by using "procedural facilitation." In procedural facilitation, all the decision making processes are made by learners in the collaborative learning environment, but computers provide guidance and suggestions to support their collaboration in a more effective matter. They designed a system called Computer-Supported Intentional Learning Environment (CSILE), which provides students with facilitating structure and tools that enable them to use their own thinking and knowledge in collaborative learning environments (Scardamalia, Bereiter, & Lamon, 1994).

Most recently, Erkens et al. (2005) used a qualitative approach to investigate the effectiveness of planning tools on the quality of online collaboration in writing an argumentative essay. The planning tools in the learning environment include an argumentation diagram and an outline facility for content linearization similar to the procedural facilitation in CSILE. These tools were designed to help students write an argumentative essay collaboratively. The researchers analyzed 290 high school students' writing assignments addressing the textual structure, segment argumentation, overall argumentation, and audience focus. They found that availability and proper use of the planning tool had a positive effect on the dialogue structure, and on the coordination processes of focusing and argumentation, as well as on text quality (Erkens, Jaspers, Prangsma, & Kanselaar, 2005).

Van Drie et al. (2005) investigated the effectiveness of procedural facilitation by way of external representational guidance. The external representation tools used in this study were argumentative diagram, list, and matrix. The results indicated that a collaborative writing task in a CSILE environment was useful for promoting historical reasoning and the learning history (van Drie, van Boxtel, Jaspers, & Kanselaar, 2005).

In contrast to a procedural facilitation approach, Choi et al. (2005) proposed a peer-questioning scaffolding framework to facilitate metacognition via asynchronous online discussion. They tested the effects of providing externalized online guidance on generation of effective peer-questioning in small group discussion. In their study, question prompts were provided to students to promote peer-questioning. The prompts included clarification or elaboration questions, counter-arguments, and context- or perspective-oriented questions. They found these prompting scaffoldings were useful to increase the frequency of student questioning behavior during collaboration, but they did not find significant differences in the quality of students' questioning (Choi, Land, & Turgeon, 2005).

The literature indicates that computer mediated peer collaboration needs to be guided and supported. In online learning environments, collaboration scaffolding can be provided in the form of explicit question prompts. These prompts can facilitate the problem-solving process and promote metacognitive thinking and questioning in peer collaboration. Therefore, design of online learning environments should consider integrating these prompts to promote effective online peer collaboration.

Discussion of Research Methods in Scaffoldings for Problem-solving

In the above sections, this paper reviewed theoretical and empirical studies, established a rationale, and demonstrated the importance of computer cognitive support for peer collaboration in problem solving. This section will review some recent empirical studies on computer supported scaffoldings specifically for problem-solving with an emphasis on the research methods of these studies in order to point out some directions for future research.

Cho and Jonassen (2002) conducted a 2×2 factorial experimental study investigating the effects of argumentation scaffolds on argumentation and problem-solving (Cho & Jonassen, 2002). Sixty undergraduate students were grouped and randomly assigned to four conditions, which were separated by two treatments: (1) well-structured versus ill-structured problems and (2) control-free online discussion and online discussion with Belvedere – a constraint-based tool that provides a framework for organizing, displaying, and recording the argumentation process. Students were asked to solve three problems collaboratively with different treatments provided. Their discussion content was analyzed addressing the quantity and quality of the argumentation. Student problem-solving process in the discussion was assessed by rubrics created by Cho and Jonassen for well-structured and ill-structured problems. For well-structured problems, the rubric was specific to the questions. For ill-structured problems, the rubrics focused on reasoned agreement-disagreement with a solution, looking for specific economic principles employed, the justification for those principles, and whether inflation is expected or unexpected. Two reviewers rated students' problem-solving reports with an inter-reliability of alpha = .964. The assessment was also determined based on consensus between raters. MANOVA and ANOVA were used for analysis. Results of this study showed that using a constraint-based argumentation scaffold positively affected the ability of groups to collaboratively construct arguments in an online environment. They also found that ill-structured problems are more affected by argumentation than are well-structured problems. However, the analyses of this study were mainly focused on the problem-solving processes reflected from the online discussion content, and students' problem-solving performances were analyzed using an overall score with ANOVA analysis. Although the discussion could reflect students' problem-solving processes, students' performance reports might be a strong resource to demonstrate students' problem-solving process as well.

Uribe, Klein, and Sullivan (2003) studied the effects of online discussion for ill-structured problem-solving (Uribe, Klein, & Sullivan, 2003). Fifty-nine students were grouped according to their GPA (high versus low) and were asked to work on ill-structured problems individually or collaboratively. The experimental program involved an introduction using an animated agent, a knowledge quiz, a problem scenario and an attitude survey. Students worked individually or in groups to solve the problems in the scenario. Students' problem-solving performances were assessed using a scoring rubric. Two raters reviewed all students' reports. Results indicated computer-mediated collaboration had positive effects on student problem-solving performance in terms of quality and time. Students in treatment groups had positive attitudes toward working collaboratively, toward the instructional program, and toward transfer of problem-solving skills. However, no significance was found in problem-solving ability, possibly because of the small sample size in this study. This study used ANOVA to analyze overall performance, but failed to address each component in the problem-solving process.

Ge and Land (2003) designed a 2×2 quasi experimental study investigating the effects of question prompts and peer interaction in solving ill-structured problems. One hundred and seventeen students were assigned to four treatment groups and asked to complete ill-structured problem-solving tasks. Four types of prompts were provided in the question prompt conditions, including (1) problem representation, (2) solution prompts, (3) justification prompts, and (4) monitoring and evaluation prompts. Students in peer interaction conditions worked in pairs in a face-to-face setting. Two raters reviewed students' problem solving reports using a scoring rubric assessing problem-solving performance. In this study the rubric and related analyses addressed the different components in problem-solving process. MANOVA and ANOVA results indicated question prompts had significantly positive effects on problem-solving performance, but peer interaction did not show significant effects. To further explore the effects of question prompts and peer interactions, this study also involved a multiple-case study with qualitative data including think-aloud protocols, observations, and interviews. The qualitative results showed that students could benefit from peer interaction in several ways, such as building on each other's ideas, eliciting responses or explanations, sharing multiple perspectives, and taking advantage of each other's knowledge and competence. This study provided a logical and practical research framework for studies in scaffolding for problem-solving. Future research may add collaborative prompts to support peer interaction along with question prompts for procedural and metacognitive support. Future research also may replicate this study in an online collaborative learning environment to gain more validity for the effectiveness of questioning and peer interaction scaffolding strategies.

Zhang (2004) furthered Ge and Land's (2003) study by moving the peer interaction to an online environment. She investigated the effects of peer controlled and externally moderated online collaboration in solving well-structured and ill-structured problems (Zhang, 2004). Approximately 300 students were assigned into approximately 80 groups of 3 to 5 individuals. There were two treatment conditions: (1) peer-controlled and (2) externally structured and moderated online collaboration. In the peer-controlled condition, students were in complete control over the collaboration process and no moderation or any other interventions were performed by the instructor or anyone else from outside of the group. In the externally structured and moderated condition, students' discussions were moderated by the instructor. Student groups were asked to solve both well-structured and ill-structured problems in social science statistics. Their reports were assessed by specified criteria for well-structured problems and a scoring rubric for ill-structured problems primarily based on mathematics problem-solving processes. The reports were scored by two reviewers independently and inter-rater reliability was obtained (Pearson Correlation was .899). An attitude survey was also given to students, addressing their perception and experiences in the online collaborative problem-solving process. The MANOVA and ANOVA results indicated that externally structured and moderated online collaboration has significantly positive effects in well-structured and ill-structured problem-solving processes. There were no significant differences in students' attitude and perception. As pointed out by the researcher, the non-significance might be due to the inefficiency of the attitude survey for capturing students' perceptions and experiences. A more robust data collection method, such as interview, would gather richer data and bring more insight to the study.

Cheung & Hew (2004), on the other hand, used a qualitative approach to analyze the content of an online discussion and reflective log used for solving ill-structured problems (Cheung & Hew, 2004). Forty-seven students were asked to solve ill-structured problems using asynchronous online discussion and reflective logs. The problem-solving process was used as a framework for their analyses. The researcher read through the content data and counted the number of times related processes occurred. The results showed that online discussion had positive effects on problem space articulation and solution generation in ill-structured problem-solving process, while the reflective logs facilitated the process of assessing the viability of alternative solutions and monitoring the problem space and solution options. This study brought new aspects to the investigation of scaffolding strategies in an online environment.

Most recently, Choi et al. (2005) investigated the effects of providing externalized online guidance on generation of effective peer-questioning in small group discussion (Choi, Land, & Turgeon, 2005). Thirty-nine students were randomly assigned to one of 10 discussion groups, and then assigned to control and treatment conditions. In the treatment condition, students could access the guidance provided in the learning interface. In the control condition, students had no access to this guidance. All groups were asked to solve problem tasks collaboratively. Their reports were assessed by two different reviewers using a scoring rubric. Interviews were conducted after experiments to gain understanding about students' perception of peer-questioning. The results suggested that peer-generated adaptive questions served a critical role in facilitating learners' reflection and knowledge reconstruction in online small group discussion. However, the study didn't find significant differences in the scores of problem-solving questions between the control and treatment groups. It may be because the question prompts in this study were focused only on collaboration and the reflective process of peer questioning, ignoring the importance of procedural and metacognitive prompts for facilitating problem-solving tasks.

These studies demonstrated some excellent research methods for investigating the effects of different scaffoldings for problem-solving and found some significant results that contribute the research literature in scaffolding and problem-solving. Although they supported the belief that question prompts and computer-mediated peer collaboration are helpful strategies for enhancing problem-solving, the following reasons provide motivation to investigate this field more deeply:

First, the body of research that has been conducted on computer-mediated peer collaboration for learning is still growing. The validity of existing studies needs to be strengthened by investigating different aspects of computer-mediated peer collaboration. To achieve the validity accumulation, we can replicate previous studies in different educational contexts, bring new strategies of collaboration to problem-solving activities, or more deeply investigate the effects of collaboration on each problem-solving component according to problem-solving models. Previous studies on computer supported peer collaboration mainly focused on the areas of reading, writing, science learning, and social studies. Studies in the area of problem-solving also need to be conducted.

Second, according to the discussion in previous sections, empirical studies and theoretical work in the literature have indicated that procedural facilitation and metacognitive question prompts have positive effects on peer collaboration in learning. Problem-solving models may provide a framework and guidelines for designing procedural and metacognitive question prompts. In Ge and Land's (2003) study, question prompts were designed according to the four components in problem-solving. The current study discussed the IDEAL models for well-structured and ill-structured problem-solving processes that can explicitly explain problem-solving processes. The use of question prompts under the IDEAL framework might bring explicit guidance for learners to support problem-solving procedural and metacognitive processes. Therefore, future studies may be conducted in order to not only endorse the validity of the problem-solving models so as to explain the principles behind problem-solving phenomena, but also to suggest scaffolding strategies for effective problem-solving.

Third, many studies investigated the effects of scaffoldings on problem-solving using scoring rubric and inter-rater reliability analyses. In these studies, the scoring rubric design is critical for analyzing problem-solving process and performance. Many previous rubrics only addressed problem solving at an overall level, however, it would be more beneficial if a rubric addressed each problem-solving component specifically. Ge and Land (2003) analyzed each component in ill-structured problem-solving processes. Specific rubrics for both well-structured and ill-structured problem-solving processes may bring more clarity to the research. IDEAL models for well-structured and ill-structured problems discussed in the previous sections may provide a theoretical framework for designing scoring rubrics in future studies.

Fourth, previous studies investigated the effects of question prompts and peer interaction in face-to-face settings, argumentation scaffolding, online collaboration scaffolding, and structured moderation for problem-solving. Future studies could integrate these scaffoldings into a bounded learning system to support collaborative problem-solving.

Previous studies on CMC peer collaboration were conducted using asynchronous communication tools (Cheung & Hew, 2004; Choi, Land, & Turgeon, 2005; Zhang & Peck, 2003). Synchronous communication methods also need to be studied in the context of scaffolding for problem-solving. New technology tools have been designed and developed, such as MSN, Google talk, and iChat, and the new features in these tools may have different effects on problem-solving processes.

CHAPTER THREE

METHODOLOGY

Purpose of the Study

The purpose of this study was to investigate the effect that computer-mediated peer collaboration and question prompts have in the process of solving ill-structured problems. This study also investigated whether question prompts can effectively moderate the peer collaboration during a problem solving task. This study hypothesized that by interacting with peers through online collaboration, students will perform better in problem solving. This study also predicted that students will perform better in problem solving when question prompts are provided. Question prompts not only can provide structure and guidance for peer collaboration, but also can offer procedural facilitation, which allows students to perform like experts, and metacognitive facilitation, which promotes higher-order thinking.

Research Questions

The following three research questions guided this study:

Question 1: Does the use of procedural and metacognitive question prompts have an effect on the process of solving ill-structured problems?

Question 2: Does the use of synchronous online peer collaboration along with collaborative reminders have an effect on the process of solving ill-structured problems?

Question 3: Does the use of synchronous online peer collaboration combined with procedural and metacognitive question prompts have an effect on the process of solving ill-structured problems?

Participants

The subjects in this study were sixty undergraduate students from a College of Education in a large South Central university. They were from three sections of an introduction to instructional technology course and two sections of an educational psychology course. These classes were face-to-face classes offered during the sixteen-week Spring semester 2006.

The subjects in this study included 86.7% Caucasian (*n* = 52), 3.3% Asian (*n* = 2), 3.3% Hispanic (*n* = 2), 1.7% African American (*n* = 1), 1.7% American Indian (*n* = 1), and 3.3% other ethnicity groups (*n* = 2). Females comprised 75% (*n* = 45) and males comprised 25% (*n* = 15). Their ages ranged from 19 to 42, with 81.7% between 20 and 23.

The subjects included 2 sophomores, 24 juniors, 31 seniors, and 3 graduate students. They were recruited from the instructional technology or the educational psychology classes. The students could choose whether or not to participate in the study. Students who completed in this study received a small amount of extra credit in their classes.

The students from these classes were pre-service teachers who had basic understanding of lesson plan design, classroom management, and human psychology and had already completed some classes related to classroom management. On average, the students had completed 1.87 educational psychology classes, 1.33 instructional classes, 1.22 classroom management classes, and 4.73 other education classes. The subjects for this study had some limited pre-knowledge and skills to solve common classroom problems. Furthermore, they had moderate confidence level for their classroom management skills (*m* = 4.45 on a 7-point scale), and high confidence level for their technology skills (*m* = 5.75 on a 7-point scale), and high confidence level for writing skills (*m* = 5.61 on a 7-point scale).

Treatments

The purpose of this study was to investigate the impact that online peer collaboration and question prompts have on the process of solving ill-structured problems. Therefore, two types of treatment were involved in the experimental design – question prompts and online peer collaboration.

<u>Treatment 1: Question Prompts</u>, including both procedural prompts and metacognitive prompts, can provide scaffoldings for problem solving (Choi, Land, & Turgeon, 2005; Davis & Linn, 2000; Ge & Land, 2003). In the present study, all the participants assigned to this treatment condition were provided with both procedural prompts and metacognitive prompts during their problem-solving processes. *Procedural prompts* were designed to help learners complete specific tasks and they provide learners with specific procedural hints or suggestions that facilitate the completion of the tasks (Rosenshine, Meister, & Chapman, 1996). In this study, procedural prompts were designed according to the IDEAL problem solving model as redefined for ill-structured problems. Examples of procedural prompts for ill-structured problems are "What is the major problem in this case?", "What are the other problems in this case?", "What are the possible strategies that you suggest to solve the problems in this case?" *Metacognitive prompts* were designed for fostering self-monitoring, self-explaining, and self-evaluation in the problem-solving process. Examples of metacognitive prompts are "Why do you

think it is the major problem?", "Why do you think these strategies can help to solve the problems?" A list of question prompts that was used in this study is provided in Appendix C.

Treatment 2: Online Peer Collaboration has been shown in many empirical studies to have positive effects on students' problem-solving (Cheung & Hew, 2004; Choi, Land, & Turgeon, 2005; Zhang & Peck, 2003). In the present study, a synchronous online communication tool, Microsoft MSN Messenger, was integrated in the learning environment to allow learners to collaboratively solve the problems in the given instructional scenarios. Microsoft MSN Messenger is one of the most popular instant messaging tools in the world. It is a free software tool that allows users to chat online via text, voice, mobile phone, or even video conversation in real time. It also allows users to express themselves with winks and dynamic display pictures or share photos, files, searches, and more instantly. All participants randomly assigned to this treatment condition were provided with a pre-registered user name to use MSN Messenger during this study. Although the participants were not required to use all the functions of MSN, for example, audio or video conferencing, they were encouraged to use text chatting, emotional icons, winks and dynamic pictures, and file sharing functions to communicate with their partners via multiple channels. In this treatment condition, two students were put in each group for collaboration. In order to ensure participants have adequate technology skills and environment familiarity, brief instruction and practice were provided to teach the participants how to use the functions of MSN Messenger required in this study. In addition, collaborative reminders were provided periodically to remind the participants to discuss the problem case with their partners. An example of the collaborative reminders is "Please discuss this case with your MSN online partner. Make sure that you and your online partner have discussed the case before you continue to answer this question."

Research Design

This study used a 2×2 factorial experimental design to address the research questions, measure the problem-solving outcomes in different treatment conditions, and then compared the group differences across conditions to identify the effects of the experimental treatments, which were referred as question prompts and online peer collaboration. One factor was the question prompts treatment. The subjects either received question prompts or worked without prompt support in the problem solving process. The other factor was the collaboration treatment. The subjects either were paired up with a peer or worked individually on the problem solving. Therefore, these two factors divided subjects into four groups and subjects were assigned to one of the four groups randomly by the computer system. The 2×2 factorial experimental design is illustrated in Table 1.

Table 1

2×2 factorial research design

		Online Peer Collaboration	
		Y	N
Question Prompts	Y	Treatment Condition 1	Treatment Condition 2
	N	Treatment Condition 3	Control Condition

Group 1: Collaboration with question prompts group. In this condition, participants were provided with both procedural and metacognitive prompts. They also worked with peers collaboratively on the problem tasks using a synchronous communication tool, MSN Messenger. At the same time, collaborative reminders were provided to remind them to collaborate with their peers.

Group 2: Collaboration without question prompts group. In this condition, participants worked with peers. Collaborative reminders were provided, but procedural and metacognitive prompts were not provided.

Group 3: Question prompts without collaboration group. In this condition, participants worked individually on the problem-solving tasks. The learning environment prompted them with procedural and metacognitive questions periodically.

Group 4: Control group. In this condition, participants worked individually on the problem tasks without any question prompts.

The subjects were given a study ID number to log in to a web-based experiment system designed by the investigator. The system randomly assigned participants into different treatment groups or the control group automatically. The system also ensured that each group had an equal number of participants.

Materials and Instruments

Materials included a survey designed to elicit demographic information and prior knowledge of classroom management, instructional animation and text for demonstrating navigating and interactive functions of the online environment, question prompts (for prompts group only) and online chatting tool (for collaboration group only), and a case scenario that contains a number of ill-structured problems. All the materials were embedded in a multimedia enhanced website created by the researcher.

Demographic Information

The demographic and prior knowledge questionnaires elicited information regarding participants' age, gender, grade level, ethnicity, academic major, and prior knowledge. The prior knowledge portion asked participants the number of educational psychology, instructional technology, and classroom management courses they had taken.

The demographic questionnaire also included one question for classroom management confidence, four questions for computer and internet skill confidence, and five questions for writing skill confidence. All these confidence questions were measured via a seven-point Likert-style scale. These questions were verified and approved by domain experts.

Instructional Materials

The instructional materials contained both classroom management knowledge reviews and instructions for technology use. The domain knowledge review materials included a text approximately 1500-word long describing a number of classroom management principles, including classroom arrangement, classroom climate, flexibility, limiting behavior, time structuring, and withitness. These materials were closely related to the problem solving tasks in this study. The subjects were asked to read through these materials to ensure that they have adequate pre-knowledge for solving the problems in the instructional tasks. These materials were presented in a text format and were enhanced with meaningful pictures.

The instruction for technology use trained participants for using the tools and resources provided in the learning environment to ensure participants have sufficient skills to use the technology in their problem solving tasks. The instruction for technology use involved three components including environment introduction, introduction to question prompts, and introduction to MSN Messenger. The environment introduction component introduced an overview and the structure, the menu and navigation system, and the interactive functions of the web-based learning environment. The introduction to question prompts component demonstrated how to respond to question prompts and interact with the learning module. The introduction to MSN Messenger component demonstrated the functions of MSN Messenger and guided participants to login and communicate with their partners. The participants practiced using MSN Messenger with their partners before they entered the case study. These instructional components were presented in three multimedia enhanced animation clips. Depending on the treatment that participants received, they were provided with different animation clips and were asked to interact with these animation clips to practice their skills in technology use. Participants in all groups received the environment introduction video, however, only the participants who received question prompts received the introduction to question prompts video, and only the participants who had access to peer collaboration received the introduction to MSN Messenger video.

The classroom management domain knowledge materials were adapted from Kauffman et al. (2005). These materials have been verified by classroom management domain experts in their study. They also have been reviewed by classroom management experts for the present study. The learning environment also was reviewed by a web-based interface design expert.

Problem Case

The instructional tasks in this study contained an ill-structured problem case presented in a movie clip format. This movie clip showed a scenario of a problematic class typical of those found in a real classroom. The teacher in this scenario had classroom management problems in her ninth grade mathematics class, such as a flexibility problem, a limiting behavior problem, a time structuring problem, and a withitness problem. All participants were asked to watch this case movie clip, analyze the problems in the case, and suggest solutions for these problems.

Since ill-structured problems are normally situated in real-world everyday practice, the investigator chose to present the problem in a more direct and authentic format by using a movie integrated in the web-based learning environment rather than textual description. This movie clip was pre-scripted, directed, and shot by the investigator. Two domain experts reviewed this problem case and gave suggestions regarding the development of the case. The video script is provided in Appendix B.

Web-Based Learning Environment

In this study, all the learning activities were administered in a web-based learning environment supported with PHP scripting language and MySQL database. This web-based learning environment was designed by the primary investigator and verified by both domain experts and interface design experts.

The learning environment included a very convenient navigation system. A top menu showed all the components of this learning module including: Introduction, Reading, Case Study, and Survey. Highlighted texts were used to indicate the current learning component. The participants were not able jump forward or go back to other components by clicking the top menu. A left menu allowed participants to access all the learning materials by clicking on each title. These materials were closely related to the classroom management issues presented in the case study. The participants were encouraged to refer to the learning materials at any time. Appendix D displays some screen shots of the web-based learning module.

Procedure

The research sites were located in two rooms in the College of Education building. Students were invited to research sites in a scheduled lab session and were distributed evenly into these rooms. When participants came to a research site, they were greeted by the research administrators and were given an informed consent form to sign. The informed consent form was approved by the IRB office. The research administrators were the investigator and a graduate student who was familiar with educational research data collection processes.

The participants were given instructional materials that introduced an overview of the procedure in this study. They were asked to read through this material and wait for the research administrators' signal to start the research. After most participants arrived, the two research administrators in both classrooms announced the start of the research and they asked the participants, at the same time, to log in to the system so that students would work on the project simultaneously. This synchronization was required for synchronous online discussion for the groups that received the online peer collaboration treatment.

When the participants logged in to the web-based learning system using an assigned ID number, the system randomly assigned them into one of the four condition groups. Then the participants started the learning module. First, the learning module presented an animation clip introducing the learning environment. It also allowed the participants to practice using the online tools provided in the learning environment, such as chatting, prompting, and hyper media. After getting familiar and comfortable with the learning environment, the participants were asked to complete a demographic survey. Then they were asked to read through the learning materials. These learning materials contained domain specific knowledge required for solving the problems in the instructional case. Next, the participants were given a case and asked to identify and solve the instructional problems in the case. This case described a scenario with some ill-structured problems that happened in classroom settings. The case scenario was presented in a video format to increase the authenticity of the problem case. The participants in different groups were provided with different scaffoldings (question prompts only, online peer collaboration only, online peer collaboration with question prompts, and control group). The research procedure for different condition groups is presented in Table 2.

The research administrators facilitated the whole research procedure, and watched for and helped students who had difficulties in completing the learning tasks. The research administrators also took observation notes when special situations occurred, such as technical problems or special requests from the students.

All the participants' responses to the question prompts, their final report, and their chatting history were recorded by the web-based learning system into a database. These data were retrieved for scoring and analysis.

Table 2

Research Procedure

	Introduction	Instruction for Environment	Practice for Prompts	Practice for MSN	Pre Treatment Questionnaire	Learning Materials	Case Study: Case Scenario	Case Study: Prompts	Case Study: MSN Collaboration
1. C&P	X	X	X	X	X	X	X	X	X
2. C only	X	X		X	X	X	X		X
3. P only	X	X	X		X	X	X	X	
4. Control	X	X			X	X	X		

Note: 1. C&P indicates collaboration with question prompts condition. P only indicates question prompts-only condition. C only indicates collaboration-only condition. Control indicates control group (Neither collaboration, nor prompts).

2. The case scenario, prompts, and MSN collaboration were concurrently available during the case study.

Since the four groups received different treatments, the time needed for completing the case study was different among the groups. Group one received the question prompts and they worked with their online partners. By responding to the question prompts and discussing with their online partners, they might spend the longest amount of time to complete the study. Group two did not receive the question prompts but they worked with their online partners. Group three only received the question prompts and they worked individually. Thus, groups two and three might spend less time to complete the study than group one. Last of all, group four worked individually without the question prompts. Therefore, this group might spend the least amount of time to complete the study compared to the other groups. In order to prevent students from leaving early and thus disturbing the students who were still working on the case study, different amounts of extra materials were added after the end of the case study in the learning module for groups two, three, and four to ensure students in each group would spend equivalent amounts of time for completing the study. These materials were closely related to classroom management, but they would not affect the result of this study. Students' responses to the extra materials were not recorded or analyzed.

Scoring

Students' problem solving reports were scored using rubrics created by the researcher assessing the extent to which students identified problems and suggested solutions. First, a domain expert was asked to go through the learning module in the control condition (without question prompts or collaboration). The qualitative report of this domain expert was reviewed and coded to discover the problem solving patterns. According to the patterns discovered in the expert's report and the redefined IDEAL ill-structured problem solving model which has been discussed in the literature review section, a scoring rubric was created for this case study. The rubric included two major components of problem solving: problem representation and problem solution. Under problem representation, the rubric specified four detailed criteria including the number of problems, description of the problem, goal definition, and justification for problem representation. Under problem solution, the rubric also specified four detailed criteria, including the number of solutions, quality of the solutions, rationales for solutions, and consequence anticipation (See Appendix E for detailed scoring rubric).

Then, another domain expert was asked to go through the learning module for the control condition in the same procedure as the first domain expert did. The response was reviewed and evaluated by using the scoring rubric. The degree to which the rubric matched the second expert's report was very high (see Appendix F). This process signified that the rubric was able to capture the characteristics of the data. Next, a report was randomly selected from each group as a sample report. The researcher invited the first domain expert to score these four sample reports using this scoring rubric together. They discussed the rubric during their scoring process. After discussion and revision, the scoring rubric was finalized for this study. Furthermore, one or two examples were identified from the sample reports for each criterion in the rubric. In Appendix E and F, a scoring rubric with examples and copies of expert reports are provided.

Besides the research investigator, a doctoral student in instructional psychology was invited to review the students' problem solving reports. Before scoring, a copy of the instructional materials and the case scenario were given to the reviewers. The reviewers were asked to read and be familiar with these materials ahead of time. All student reports were retrieved from the database and were printed out. Every report was labeled with an ID number on the top of each page to identify the treatment group of the participant. The reports were randomly ordered and then stapled together. The ID numbers were sealed so that the reviewer was not able to identify the group information while evaluating the reports.

Next, the reviewers met and read the instructional materials aloud together to make sure both reviewers understood the learning materials well. During the reading process, some keywords were identified from each topic of the learning materials. They also discussed each topic to make sure they had agreement in understanding each concept. Then the researcher explained the scoring procedure to the other reviewer and explained the scoring rubric with the expert report as an example. The reviewers practiced scoring four samples randomly selected from the data and discussed the scoring in order to reach an agreement on the scoring criteria.

The reviewers then scored each student case independently. After independent scoring, the two reviewers met again and compared scores for each case. They discussed the scores for each case until 100% agreement was searched for each case. Both reviewers' independent scores and the final scores were entered into SPSS for analysis.

Hypotheses

Based on the research questions of the current study and prior research findings, the following hypotheses were generated:

1. Students working with question prompts will perform better in problem solving activities than students working without question prompts.

2. Students working with online peer collaboration will perform better in problem solving activities than students working without peer collaboration.

3. Students working with both online peer collaboration and question prompts will perform better than those in the other groups.

Data Analyses Procedure

After the research data were collected, scored, and organized, they were analyzed using various quantitative methods. The data sources included the scoring results of students' problem-solving reports from the case study and their self-report questionnaire. The analyses included internal reliability and inter-rater reliability analysis, correlation analysis, and MANOVA and ANOVA analyses.

Internal Reliability and Inter-rater Reliability Analysis

Internal reliability indicates how well the individual items of a scale reflect a common construct. This is a prerequisite for validity. In this study, technology skill confidence items and writing skill confidence items were created for the present study. The internal reliabilities for these two instruments need to be calculated to ensure all the items measure the same construct consistently.

Inter-rater reliability measures the agreement among coders in their analysis. It addresses the consistency of the implementation of a rating system. In this study, the inter-rater reliability provides some evidence of how well the rubric measures students' problem solving achievements. It was calculated for the scoring rubric using Pearson's bivariate correlation, which indicates the linear relationship between two variables. A stronger relationship between the scores of two raters suggests higher inter-rater reliability for the scoring rubric. If there is not significant correlation between the scores of the two raters, the inter-rater reliability for the scoring rubric would be shown very low, and thus the scoring rubric would not be valid for data scoring.

Correlation Analysis

The Pearson's correlation is normally used to find a correlation between at least two continuous variables. The absolute value for a Pearson's can fall between 0.00, which indicates no correlation, and 1.00, which indicates perfect correlation. In this study, the correlation analyses were used for three purposes. First, it was used to assess the inter-rater reliability for the scoring rubric. Second, the Persons' correlation was used to examine the relationship among students' classroom management confidence, technology confidence, writing confidence, and the problem solving scores of their reports. The results of this analysis would suggest whether or not there should be covariates involved in further multivariate analyses. Third, the Person's correlation also was used to examine the relationship among the scores of problem solving reports. The result of this analysis also would provide statistical justification for using Multivariate Analysis of Variance (MANOVA) (Stevens, 2002). If significant correlation patterns were found among the components of problem solving, MANOVA would be shown to be appropriate and meaningful for the data analysis. Otherwise, the researcher would need to seek other statistic approaches to examine the group differences for problem solving.

MANOVA and ANOVA

To analyze the group differences in students' problem solving reports, multiple dependent variables should be considered when the problem solving process is decomposed to identifying problems, defining problems, exploring solutions, acting on solutions, and looking back. In this case, multivariate analysis such as MANOVA should be considered. The reasons that MANOVA should be considered rather than using a set of univariate tests are: (1) The use of fragmented univariate tests leads to a greatly inflated overall type I error rate; (2) The univariate tests ignore the correlations among the variables; (3) Although the groups may not be significantly different on any of the variables individually, jointly the set of variables may reliably differentiate the groups; and (4) Multivariate tests can detect differences which will not be reflected by the total test scores (Stevens, 2002).

When significance was found in MANOVA on the problem solving reports, the investigator went further and conducted a set of ANOVA to detect significances in the univariate level.

Challenges

Although this design considered many possible outcomes of the study, there were still some challenges that might have influenced the results of this study or subsequent replications of this study.

First, since this study was conducted in an online environment, the web servers had to be stable during the experiments. There were two web servers involved in this study. One was the web and database server located in the Education building that delivered the instruction and problem cases, and collected participants' responses and reports. This server had been demonstrated to be relatively stable since it was an internal server used only for this study. However, potential risks to cause the server failure still existed including electricity failure, internet connection failure, and virus protection failure. Multiple tests on this server were conducted before the data collection started.

Another server involved in this study was MSN server which allowed the communications among MSN Messengers. Microsoft Corporation performs maintenance on this server periodically. When the server is down for maintenance, communications among MSN Messengers is disabled. This situation could have led to communication failure during the data collection process. Therefore, the technical problems are major challenges that can impact the success of similar studies.

Second, in order to increase the authenticity of the online learning environment, the research sites were located in two different study rooms. The students in the collaboration condition collaborated only with the students in the other location. This brought challenges to the research administration. Another researcher, besides the primary investigator, was needed. He or she had to be trained to administer the research process. In addition, since this study involved synchronous computer-mediated communication, it requires peers to be available at the same time period. The two administrators had to coordinate to ensure that each student started the search at the same time and students in each collaboration group were able to log on to MSN Messenger at the same time. The learning environment also needed to be designed to allow learners in the collaboration condition to start communication at the same time.

Third, since students in each treatment condition received a different treatment, the amount of time needed for completing the study was different. In order to prevent students who finished early from disturbing those who were still working on their project, extra materials were added to the learning module to ensure that students in each treatment condition would spend approximately same amount of time completing the study. However, even after the extra materials had been added, the amount of time needed for completing the study still differed among students. Fast readers or writers might still leave early. Therefore, the research administrators needed to ask students to leave quietly to minimize the interpersonal disturbance.

Furthermore, to ensure an appropriate effect size in this study, an adequately large sampling size had to be ensured. However, since this study lasted about two hours for each participant, the recruitment of subjects might be challenging. Students might not be willing to participate in this study, and might seek other easier research opportunities for their class credits.

CHAPTER FOUR

RESULTS

This chapter presents the results of quantitative data analyses for this study. First reported are results of reliability analyses. Then correlation analyses are reported, which determines whether covariates need to be involved in the multivariate analyses that follow. The correlation results also determine whether statistical justification exists to support the multivariate analyses. Then, the results of multivariate analyses of variance (MANOVA) and follow-up ANOVAs are reported. Finally, the results of MANOVA and ANOVAs will be presented relevant to the research questions and hypotheses.

Reliability Analyses

Internal Reliability for Confidence Measures

A reliability test, Cronbach α, was used to measure the internal consistency of the instruments measuring technology skill confidence and writing skill confidence (Cronbach, 1990). The Cronbach α score of the technology skill confidence items was .750. Means for the technology skill confidence items ranged from 5.233 to 6.450 on a 7-point scale. The Cronbach α score of the writing skill confidence items was .944. Means for the writing skill confidence items ranged from 5.333 to 5.767 in a 7-point scale. The mean score for the classroom management confidence item was 4.450 in a 7-point scale. The results were presented in Table 3. More detailed information on the item analysis and the example items is provided in Appendix A.

Table 3

Internal Reliability, Means, and Standard Deviation of Technology Skill Confidence and Writing Skill Confidence.

Variable	*Cronbach's Alpha*	*Items*	*Mean*	*Std. Deviation*
TechSkill	.750	TechSkill1	5.2333	1.34501
		TechSkill2	6.4500	.92837
		TechSkill3	5.9333	.84104
		TechSkill4	5.3833	1.19450
WritingSkill	.944	WritingSkill1	5.7000	1.01347
		WritingSkill2	5.7667	.99774
		WritingSkill3	5.6000	.97772
		WritingSkill4	5.6333	.99092
		WritingSkill5	5.3333	1.11487

Inter-rater Reliability for Scoring Rubric

Inter-rater reliability was calculated by using Pearson Bivariate Correlation. Table 4 and Table 5 show the correlation matrix of the scores of the two reviewers. Although the matrices show all the correlations among the problem solving variables, only the correlations between the scores of the two reviewers on the same variables were of interest for the purpose of measuring inter-rater reliability. The results indicated that there were significant correlations between the scores of the two reviewers on problem representation 1, representation 2, representation 3, and representation 4. There were significant correlations between the scores of the two reviewers on problem solution 1, solution 2, solution 3, and solution 4. The magnitudes of these correlations were large according to Cohen’s standard (Cohen, 1988). The strong correlation among these variables of interest suggested that the agreement between the two reviewers in their scoring was high, thus the inter-rater reliability for the scoring rubric was high which indicated the implementation of a rating system was consistent between reviewers.

Table 4

Correlations of the Problem Representation Scores between Rater 1 and Rater 2

	Repre_1 (Rater_2)	Repre_2 (Rater_2)	Repre_3 (Rater_2)	Repre_4 (Rater_2)
Repre_1 (Rater_1)	**.856(**)**	.326(**)	.397(**)	.288(*)
Repre_2 (Rater_1)	.127	**.745(**)**	.318(**)	.667(**)
Repre_3 (Rater_1)	.319(**)	.593(**)	**.738(**)**	.606(**)
Repre_4 (Rater_1)	.278(*)	.502(**)	.527(**)	**.621(**)**

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

Note: 1. Repre_1 indicates the number of problems, Repre_2 indicates problem description, Repre_3 indicates goal definition, and Repre_4 indicates justification for problem representation. These are the four components of the problem representation part of the scoring rubric.

2. Rater_1 and Rater_2 indicate the two reviewers.

Table 5

Correlations of the Problem Solution Scores between Rater 1 and Rater 2

	Solution _1 (Rater_2)	Solution _2 (Rater_2)	Solution _3 (Rater_2)	Solution _4 (Rater_2)
Solution_1 (Rater_1)	**.698(**)**	.270(*)	.427(**)	.276(*)
Solution _2 (Rater_1)	.220(*)	**.556(**)**	.411(**)	.389(**)
Solution _3 (Rater_1)	.185	.407(**)	**.581(**)**	.600(**)
Solution _4 (Rater_1)	.100	.352(**)	.283(*)	**.711(**)**

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

Note: 1. Solution_1 indicates the number of solutions, Solution_2 indicates the quality of solutions, Solution_3 indicates solution justification, and Solution_4 indicates consequence anticipation. These are the four components of the problem solution part of the scoring rubric.

Correlation Analyses

As described in Chapter Three, correlation analysis was used for three purposes. First, it was used to assess the inter-rater reliability for the scoring rubric which has been discussed in the previous section.

Second, the Pearsons' correlation was used to examine the relationship among students' classroom management confidence, technology confidence, writing confidence, and problem solving scores. The purpose of this examination was to determine whether covariates needed to be involved in the later multivariate analyses. A potential covariate is any variable that is significantly correlated with the dependent variable (Stevens, 2002). Multivariate analysis of covariance reduces systematic bias introduced by the potential covariate and neutralizes the effect of the potential covariate in the experiment. Therefore, in order to examine whether a covariate accounts for the variance among groups, the first step is to check the correlations among the variables of interest.

The results are shown in the correlation matrix (see Table 6). The means, standard deviations, and sample items of classroom management confidence, technology skills confidence, and writing skills confidence are listed in Table 7.

Table 6

Correlation between Confidence Scores and Problem Solving Scores

	Rep_1	Rep_2	Rep_3	Rep_4	Sol_1	Sol_2	Sol_3	Sol_4
CM	-.077	.046	.032	-.019	-.292(*)	-.054	-.058	-.009
Tech	-.023	.112	.095	.082	-.089	-.078	-.002	-.085
Writing	.038	-.068	.182	.086	-.007	-.067	.036	.147

* Correlation is significant at the 0.05 level (2-tailed).

Note: 1. Rep_1 indicates the number of problems, Rep_2 indicates problem description, Rep_3 indicates goal definition, and Rep_4 indicates justification for problem representation. These are the four components of the problem representation part of the scoring rubric.

2. Sol_1 indicates the number of solutions, Sol_2 indicates the quality of solutions, Sol_3 indicates solution justification, and Sol_4 indicates consequence anticipation. These are the four components of the problem solution part of the scoring rubric.

3. CM indicates student confidence in their own classroom management knowledge, Tech indicates student confidence in their own technology skills, and Writing indicates student confidence in their own writing skills.

Table 7

Means, Standard Deviations, and Samples of Confidence Items

	Mean	*Std. Deviation*	*Sample Items*
CM	4.450	1.080	How much do you know about how to manage a classroom effectively?
Tech	5.750	.829	I can successfully use computers to do things related to my classes.
Writing	5.607	.922	I can successfully complete all activities with my writing skills.

Classroom management confidence and the number of problem solutions had a significant negative correlation with a moderate magnitude (Cohen, 1988), however, the data did not show any other significant correlations between the confidence scores and problem solving scores. With problem solving being broken down into eight subcomponents, the single significant correlation between classroom management confidence and the number of problem solutions does not provide sufficient evidence that classroom management confidence impacts student problem solving. The results provide no strong evidence that student self-reported classroom management confidence, technology skill confidence, or writing skill confidence would contribute to the group variance on problem solving scores. Therefore, none were used as covariates in the following MANOVA tests.

Third, the Pearson's correlation also was used to examine the relationship among the scores of problem solving reports. The results of this analysis provide statistical justifications for using Multivariate Analysis of Variance (MANOVA) (Stevens, 2002). If a significant correlation pattern is found among the components of problem solving, MANOVA is appropriate and meaningful for the data analysis. Otherwise, the researcher would need to seek other statistic approaches to analyze the group differences for problem solving.

Pearson's bivariate correlations were calculated among problem solving process components. In the correlation matrix (see Table 8), a moderately strong correlation pattern was revealed among the variables. The four problem representation variables were all significantly correlated with each other. Among the four problem solution variables, there were significantly correlations, except that the number of solutions and solution consequence anticipation was not correlated significantly. With regard to the correlations between problem representation variables and problem solution variables, there also were significances, such as (1) the number of problems represented and the number of solutions, (2) problem description and quality of solutions, (3) problem description and the rationale for solutions, (4) goal definition for representation and quality of solution, (5) rationale for representation and quality of solutions, and (6) rationale for representation and rationale for solutions also were significantly correlated. All these correlations had moderate to large magnitudes (Cohen, 1988). This correlation pattern indicates all these problem solving variables were interrelated with each other and together reflect different aspects of student problem solving abilities. Therefore, multivariate analysis of variance was used to examine the difference in student problem solving abilities among groups.

Table 8

Correlation Matrix among Problem Solving Process Components

	Rep_1	Rep_2	Rep_3	Rep_4	Sol_1	Sol_2	Sol_3	Sol_4
Rep_1	1	.232*	.324**	.263*	.452**	.123	.188	.080
Rep_2	-	1	.536**	.686**	.087	.435**	.261*	.057
Rep_3	-	-	1	.728**	-.025	.404**	.212	.073
Rep_4	-	-	-	1	.151	.529**	.417**	.212
Sol_1	-	-	-	-	1	.297*	.372**	.178
Sol_2	-	-	-	-	-	1	.562**	.370**
Sol_3	-	-	-	-	-	-	1	.567**
Sol_4	-	-	-	-	-	-	-	1

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Multivariate Analysis of Variance

To discover the differences in student problem solving among groups in different treatment conditions (Collaboration with prompts, collaboration without prompts, individual with prompts, and controlled individual without prompts), a 2×2 multivariate analysis of variance (MANOVA) was calculated using SPSS. The dependent variables involved in this MANOVA included both problem representation components (number of problems, problem description, goal definition, and justification for representation) and problem solution components (number of solutions, quality of solution, rationale for solution, and solution consequence anticipation). The grouping factors involved in this MANOVA included question prompts and online collaboration. Given a sample size of

60, in order to balance type I error and type II error, all the analyses were tested at a significance level of .05.

The results of the MANOVA showed a significant main effect of question prompts on problem solving variables with a large effect size (Cohen, 1988). However, the online collaboration treatment had no significant main effect on problem solving variables. Moreover, no significant interaction between these factors occurred (Results are shown in Table 9). The results of the Box's test indicated the data satisfied the homogeneity assumption of the MANOVA test [$F(108, 6848.7) = .919$, $p>.05$].

Table 9

Results of MANOVA

Effect		*Value*	*F*	*Sig.*	*Effect Size*	*Observed Power*
Prompts	Wilks' Lambda	**.725**	**2.323**	**.034**	**.275**	**.828**
Chat	Wilks' Lambda	.928	.473	.870	.072	.196
Prompts * Chat	Wilks' Lambda	.838	1.184	.328	.162	.485

Note: Hypothesis df = 8.000, Error df = 49.000

The results of the MANOVA tests reveal the following findings in terms of the research questions of this study.

In response to "Research Question One: Does the use of procedural and metacognitive question prompts have an effect on the process of solving ill-structured problems?", the results suggest that the use of procedural and metacognitive question prompts had a significant main effect on the process of solving ill-structured problems in this study.

In response to “Research Question Two: Does the use of synchronous online peer collaboration along with collaborative reminders have an effect on the process of solving ill-structured problems?”, the results suggest that the use of synchronous online peer collaboration along with collaborative reminders did not have a significant main effect on the process of solving ill-structured problems in this study.

In response to “Research Question Three: Does the use of synchronous online peer collaboration combined with procedural and metacognitive question prompts have an effect on the process of solving ill-structured problems?”, the lack of significant interaction suggests that the use of synchronous online peer collaboration combined with procedural and metacognitive question prompts did not have a significant main effect on the process of solving ill-structured problems.

To explore group differences among the specific problem solving different treatment groups, another MANOVA test was conducted using individual problem representation components and problem solution components as dependent variables. This MANOVA used “group” as the only grouping factor. The grouping factor divided the subjects into four groups (Q&C group, C only group, Q only group, and control group). Therefore, it was a 1×4 MANOVA test. However, the main effect for the grouping factor was not significant at a significance level of .05. Followed up ANOVA tests revealed a significant effect for the grouping variable only on the number of problems [$F(3, 56) = 3.07$, $p<.05$] and the number of solutions [$F(3, 56) = 7.34$, $p<.01$]. The grouping variable had no other significant effect on the other dependent variables.

Table 10 shows the descriptive statistics including means and standard deviations of each problem solving component in each treatment condition sorted by the two treatment factors: question prompts and online peer collaboration. These variables will be discussed in more detail in the following sections.

Table 10

Means and Standard Deviation of Problem Solving Components

	Collaboration			*Individual*			*Total*		
	M	*SD*	*n*	*M*	*SD*	*N*	*M*	*SD*	*N*
Representation_1									
Prompts	2.47	.92	15	2.50	1.10	16	2.48	1.00	31
No Prompts	2.21	1.48	14	1.47	.64	15	1.83	1.17	29
Total	2.34	1.20	29	2.00	1.03	31	2.17	1.12	60
Representation_2									
Prompts	7.00	2.17	15	5.88	2.39	16	6.42	2.32	31
No Prompts	5.36	2.76	14	5.67	2.82	15	5.52	2.75	29
Total	6.21	2.57	29	5.77	2.57	31	5.98	2.55	60
Representation_3									
Prompts	5.07	2.46	15	3.81	2.97	16	4.42	2.77	31
No Prompts	2.86	2.74	14	3.07	2.69	15	2.97	2.67	29
Total	4.00	2.79	29	3.45	2.81	31	3.72	2.79	60
Representation_4									
Prompts	6.00	3.34	15	4.50	3.79	16	5.23	3.60	31
No Prompts	3.00	3.53	14	3.33	3.27	15	3.17	3.34	29
Total	4.55	3.70	29	3.94	3.54	31	4.23	3.60	60
Solution_1									
Prompts	2.53	1.25	15	3.06	1.29	16	2.81	1.28	31
No Prompts	1.64	1.28	14	1.67	1.29	15	1.66	1.26	29
Total	2.10	1.32	29	2.39	1.45	31	2.25	1.39	60
Solution_2									
Prompts	5.40	1.68	15	5.69	2.24	16	5.55	1.96	31
No Prompts	4.21	2.61	14	3.93	1.67	15	4.07	2.14	29
Total	4.83	2.22	29	4.84	2.15	31	4.83	2.16	60
Solution_3									
Prompts	5.13	2.80	15	4.69	3.46	16	4.90	3.11	31
No Prompts	2.36	2.76	14	3.33	3.20	15	2.86	2.98	29
Total	3.79	3.08	29	4.03	3.35	31	3.92	3.20	60
Solution_4									
Prompts	3.73	3.63	15	3.31	3.84	16	3.52	3.69	31
No Prompts	1.86	3.16	14	2.27	3.56	15	2.07	3.32	29
Total	2.83	3.49	29	2.81	3.68	31	2.82	3.56	60

Note: 1. M indicates mean, SD indicates standard deviation, and n indicates number of participants.

2. The possible range of scores for Problem Representation_1 and Solution_1 is 0 – 5, The possible range of scores for the other variables of problem solving is 0 – 9.

Univariate Analysis of Variance

Following the MANOVA test, to locate the sources of the significance that question prompts had on the process of problem solving and to discover the effects that different treatments had on dependent variables at a univariate level, a series of univariate analysis of variance (ANOVA) were conducted. The dependent variables involved in these ANOVAs were representation components including (1) the number of problems, (2) problem description, (3) goal definition, and (4) justification for representation, and problem solution components including (1) the number of solutions, (2) quality of solution, (3) rationale for solution, and (4) solution consequence anticipation. The different treatments involved in these ANOVAs were question prompts and online collaboration. Given a sample size of 60, in order to balance type I error and type II error, all the analyses were tested at a significance level of .05.

The Number of Problems

The number of problems is the first criteria in the problem solving scoring rubric. It reflected the thoroughness of students' problem representation in their problem solving. The maximum number of problems in the study was 5. Therefore, the scores for this criterion ranged from 0 to 5.

The results of a 2×2 ANOVA on this dependent variable indicate that question prompts had a significant effect on the number of problems identified in the problem solving process with a moderate effect size (Cohen, 1988). Means indicated that participants who received question prompts identified significantly more problems (m =

2.48, *sd* = 1.00, *n* = 31) in the problem representation phase than did those who did not receive question prompts (*m* = 1.83, *sd* = 1.17, *n* = 29).

There was not a significant main effect for online peer collaboration or the interaction of question prompts and online peer collaboration. Table 11 shows the results of the ANOVA test. Levene's test suggests the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = 2.673$, $p > .05$].

Table 11

ANOVA for the Number of Problems

Source	*Df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	**5.427**	**.023**	**.088**	**.629**
Collaboration (C)	1	1.675	.201	.029	.246
P X C	1	2.002	.163	.035	.285
Error	56				

Description of the Problems

The description of the problems reflected how well the problem symptoms had been described in students' reports. Students who described the problem symptoms clearly and with specific examples got the maximum score of 9 and students who failed to describe the problem symptoms got a score of 0. Therefore, the scores for this criterion ranged from 0 to 9.

The results of a 2×2 ANOVA on this dependent variable indicate no significant main effect for question prompts or online peer collaboration or the interaction between question prompts and online peer collaboration. Table 12 shows the results of the ANOVA test.

Levene's test indicates the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = .666$, $p>.05$]. Means of this variable indicated that students in all groups performed fairly well on describing the symptoms of the problems ($m = 7.00$, $sd = 2.17$, $n = 15$ for Group 1; $m = 5.36$, $sd = 2.76$, $n = 14$ for Group 2; $m = 5.88$, $sd = 2.39$, $n = 16$ for Group 3; $m = 5.67$, $sd = 2.82$, $n = 15$ for Group 4).

Table 12

ANOVA for Description of the Problems

Source	*Df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	1.982	.165	.034	.283
Collaboration (C)	1	.385	.538	.007	.094
P X C	1	1.190	.280	.021	.285
Error	56				

Defining the Goal of Problems

Defining the Goal of Problems reflected how well the participants analyzed the problem symptoms, defined the goal of the problems, and categorized the type of the problems. Students who defined the goal of the problems clearly and categorized the problems into the correct categories with detailed explanations got the maximum score of 9. Students who failed to define the goal of the problems got a score of 0. Therefore, the scores for defining the goal of problems ranged from 0 to 9.

The results of a 2×2 ANOVA on the dependent variable of defining the goal of problems indicate that question prompts had a significant effect on defining the goal of the problems which had been identified in the problem solving process a moderate effect size. Means indicate that participants who received question prompts performed significantly better in defining the goal of the problems ($m = 4.42$, $sd = 2.77$, $n = 31$) in their problem representation than did those who did not receive question prompts ($m = 2.97$, $sd = 2.67$, $n = 29$).

There was no significant main effect for the online peer collaboration or the interaction between question prompts and online peer collaboration. Table 13 shows the results of the ANOVA test. Levene's test suggests that the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = .504$, $p>.05$].

Table 13

ANOVA for Defining the Goal of Problems

Source	*Df*	*F*	*P*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	**4.399**	**.040**	**.073**	**.540**
Collaboration (C)	1	4.083	.462	.010	.113
P X C	1	1.079	.303	.019	.175
Error	56				

Providing Justification for Problem Representation

Providing justification for problem representation was a criterion in the scoring rubric that reflected students' metacognitive skill in the problem representation process. It examined how well students explained why they thought the issues they identified in the case study were problems and why the problems should be defined or categorized. The scores for this criterion were ranged from 0 to 9.

The results of a 2×2 ANOVA on this dependent variable indicated that question prompts had a significant effect on providing justification for problem representation in the problem solving process with a moderate effect size (Cohen, 1988). Means indicate that participants who received question prompts performed significantly better in providing justifications for problem representation ($m = 5.23$, $sd = 3.60$, $n = 31$) in their problem solving process than did those who did not receive question prompts ($m = 3.17$, $sd = 3.34$, $n = 29$).

There was no significant main effect for the online peer collaboration or the interaction between question prompts and online peer collaboration. Table 14 shows the results of the ANOVA test. Levene's test suggests the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = .726$, $p>.05$].

Table 14

ANOVA for Providing Justification for Problem Representation

Source	*Df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	**5.323**	**.025**	**.087**	**.621**
Collaboration (C)	1	.417	.521	.007	.097
P X C	1	1.031	.314	.018	.170
Error	56				

The Number of Solutions

The number of solutions is a dependent variable that reflects the quantitative variance of the solutions in students' problem solving. Corresponding with problem representation, the scores of this criterion ranged from 0 to 5.

The results of a 2×2 ANOVA on this dependent variable indicate that question prompts had a significant effect on the number of solutions suggested by the participants with a large effect size (Cohen, 1988). Means indicate that participants who received question prompts provided significantly more solutions for the problems in the case study (m = 2.81, sd = 1.28, n = 31) than did those who did not receive question prompts (m = 1.66, sd = 1.26, n = 29).

There was no significant main effect for the online peer collaboration or the interaction between question prompts and online peer collaboration. Table 15 shows the results of the ANOVA test. Levene's test suggests the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = .011$, $p>.05$].

Table 15

ANOVA for the Number of Solutions

Source	*Df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	**12.007**	**.001**	**.177**	**.926**
Collaboration (C)	1	.702	.406	.012	.131
P X C	1	.587	.447	.010	.117
Error	56				

The Quality of Solutions

The quality of solutions went further to reflect how well the solutions could improve the problem situation, how well the solutions were linked to the problems that had been identified, how clearly the problem solutions were described, and how applicable the solutions were to the problem situation. The scores for this criterion ranged from 0 to 9.

The results of a 2×2 ANOVA on the dependent variable of the quality of the solutions indicate that question prompts had a significant effect on the quality of the solutions provided by the participants in the problem solving process with a large effect size (Cohen, 1988). Means indicated that participants who received question prompts suggested significantly higher quality of solutions (m = 5.55, sd = 1.96, n = 31) than did those who did not receive question prompts (m = 4.07, sd = 2.14, n = 29).

There was no significant main effect for the online peer collaboration and no significant interaction between question prompts and online peer collaboration. Table 16 shows the results of the ANOVA test. Levene's test suggests that the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = 1.44$, $p>.05$].

Table 16

ANOVA for the Quality of Solutions

Source	*Df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	**7.473**	**.008**	**.118**	**.766**
Collaboration (C)	1	.000	.995	.000	.050
P X C	1	.279	.599	.005	.081
Error	56				

Providing Rationales for Solutions

Providing rationale for solutions was a criterion in the scoring rubric that reflected students' metacognitive skills in the solution seeking process. It examined how well students explained why they thought those solutions could improve the problem situation. The scores for this criterion ranged from 0 to 9.

The results of a 2×2 ANOVA on the dependent variable of providing rationales for solutions indicated that question prompts had a significant effect on providing rationales for the solutions suggested by participants during the problem solving process with a moderate large effect size (Cohen, 1988). Means indicate that participants who received question prompts performed significantly better in providing rationales for the problem solutions they suggested (m = 4.90, sd =3.11, n = 31) than did those who did not receive question prompts (m = 2.86, sd = 2.98, n = 29).

There was no significant main effect for the online peer collaboration condition and no significant interaction between question prompts and online peer collaboration. Table 17 shows the results of the ANOVA test. Levene's test suggested that the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = .750$, $p>.05$].

Table 17

ANOVA for Providing Rationales for Solutions

Source	*Df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	**6.723**	**.012**	**.107**	**.722**
Collaboration (C)	1	.111	.740	.002	.062
P X C	1	.797	.376	.014	.142
Error	56				

Anticipating the Consequences of Solutions

Anticipating the consequence of solutions was a criterion in the scoring rubric that examined how well the students could anticipate the consequence of the solutions that they proposed. This process enables problem solvers to anticipate positive action outcomes and prevent negative action outcomes. When negative outcomes are recognized, problem solvers usually go back and find out alternative solutions or strategies (Bransford & Stein, 1993). The scores for this criterion ranged from 0 to 9.

The results of a 2×2 ANOVA on the dependent variable of anticipating the consequences of solutions indicate there was no significant main effect for question prompt condition, the online peer collaboration condition or the interaction. Table 18 shows the results of the ANOVA test. Levene's test suggests that the homogeneity assumption for ANOVA was satisfied [$F(3, 56) = .953$, $p>.05$]. Means of this variable indicate that students in all groups performed poorly on anticipating the consequences of the problem solutions (m = 3.73, sd = 3.63, n = 15 for Group 1; m = 1.86, sd = 3.16, n = 14 for Group 2; m = 3.31, sd = 3.84, n = 16 for Group 3, m = 2.27, sd = 3.56, n = 15 for Group 4).

Table 18

ANOVA for Anticipating the Consequences of Solutions

Source	*df*	*F*	*p*	*Effect Size*	*Power*
		Between Subjects			
Prompts (P)	1	2.509	.119	.043	.334
Collaboration (C)	1	.000	.995	.000	.050
P X C	1	.203	.654	.004	.073
Error	56				

Summary of Results

By comparing the differences among groups on problem solving variables, the results of the MANOVA tests indicate that question prompts had a significant main effect on the overall problem solving process. However, there was no significant main effect for online collaboration or significant interaction of prompts and collaboration at the overall level. The follow-up ANOVA tests revealed that question prompts had significant main effects on both the problem representation variables (including the number of problems, defining the goal of the problems, and providing justification for problem representation), and the problem solution variables (including the number of solutions, the quality of solutions, and providing rationales for solutions). However, the main effect of question prompts for the description of the problems and the solution consequence anticipation was not significant at the univariate level. There were no significant main effects of online peer collaboration or significant interaction at the univariate level.

When students were provided with question prompts they identified significantly more problems in the case study. They defined the goal of the problem and categorized the problems significantly more clearly than the students who did not receive the question prompts. They also provided comprehensible justifications for the problem representation. Furthermore, compared to the students who did not receive question prompts, students who received question prompts suggested significantly higher number of reasonable solutions for improving the problem situation. Their solutions had significantly higher quality and were linked to the problem that had been identified. They also provided comprehensible rationales for the problem solutions. Therefore, the results indicate that students who received question prompts performed significantly better in problem solving activities than did students working without question prompts. These results provide evidence to support Hypothesis 1. However, with no significant effects of online peer collaboration nor significant interaction, Hypotheses 2 and 3 are not supported by the research data.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

Overview of the Findings

The purpose of this study was to investigate the effects that question prompts and computer-mediated peer collaboration have in the process of solving ill-structured problems. This study also investigated whether question prompts can effectively moderate the peer collaboration during a problem solving task. Question prompts and computer-mediated peer collaboration are two promising scaffolding strategies that have the potential to support student problem solving. Problem solving is a complex process that involves identifying the problem, defining the goal of the problem, exploring possible solutions, acting on the solutions and anticipating the consequence of the solutions, and looking back process. This study not only examined the effects of these scaffolding strategies on problem solving at an overall level, but also went further and investigated the influences of these scaffolding strategies on each component of the problem solving process.

In this study, MANOVA and ANOVAs were used to examine the effects of question prompts, online peer collaboration, and their interaction on problem solving process. The results of these analyses reveal some interesting findings related to the research questions and the hypotheses of this study. In this chapter, these findings are discussed in response to the research questions. Furthermore, this chapter discusses the implications for instructional designers, educators in web-based learning environments, and educational researchers, followed by a discussion of the limits of this study and directions for future research.

Research Question 1: Does the use of procedural and metacognitive question prompts have an effect on the process of solving ill-structured problems?

The results of this study suggested that students who received procedural and metacognitive question prompts performed significantly better in solving ill-structured problems than did students working without question prompts. More specifically, the univariate results suggested that students who received procedural and metacognitive question prompts outperformed those who did not receive question prompts on both problem representation process, including (a) the number of problems identified, (b) defining the goal of the problems, and (c) providing justifications for problem representation, and problem solution seeking process, including (a) the number of solutions suggested, (b) the quality of the solutions, and (c) providing rationales for solutions.

These results support the hypothesis for research question one. They also supported previous research that found prompting students with appropriate questions including both procedural questions and metacognitive questions was an effective scaffolding strategy to support students in complex cognitive activities such as problem solving (Ge & Land, 2003, 2004; Kauffman et al., 2005; King, 1991, 1992). The significant effects of question prompts on both problem representation and solution seeking is consistent with the findings in Ge and Land’s (2003) study that found question prompts had significant effects on all four problem-solving processes, including (a) problem representation, (b) developing solutions, (c) making justification and (d) monitoring and evaluating solutions.

The present findings also suggest that the procedural and metacognitive question prompts not only facilitated student completion of the tasks of solving ill-structured problems (such as identifying the problem, defining the goal, and seeking potential solution), but also promoted students' metacognitive thinking in the problem solving process (such as providing justification for problem representation and providing rationale for solution).

The effectiveness of question prompts on facilitating the problem solving procedure supported the findings of a series of studies conducted by King. She found that procedural prompts could facilitate learners' understanding of domain knowledge by activating prior knowledge and elaborating their thinking process (King, 1991a, 1991b, 1992, 1994). The findings of procedural prompts in the present study also support Zellermayer et al.'s study, which illustrated that procedural question prompts offered guided stimulation of higher-order processes of planning, diagnosing, and revising, which novices were not likely to activate on their own (Zellermayer, Salomon, Globerson, & Givon, 1991). In the present study, the procedural question prompts guided students to go through each component in the process of solving ill-structured problems. These prompts provided hints and guidance that directed students' problem solving to a more expert-like level. Students who received question prompts identified a significantly higher number of problems in the problem case and suggested a significantly higher number of solutions to improve the problem situation than did those who did not receive question prompts. This finding suggests that question prompts broadened students' vision of solving ill-structured problems. Question prompts helped students to analyze the problems from multiple aspects, thus to more thoroughly consider the problem situation. They also helped students to seek problem solutions to improve each aspect of the problem situation. Moreover, students who received question prompts defined the goal of the problems more clearly and categorized the problems into the correct categories with detailed explanation better than did those who did not receive prompts. Students who received question prompts provided significantly higher quality solutions than did those who did not receive prompts. The high quality solutions were clearly described, well linked to the problems, and reasonable and applicable to the problem situation. This finding suggests that question prompts also improved students' higher-order thinking in solving ill-structured problems. They helped students to identify the roots of the problems rather than simply stating superficial problem facts. They also helped students to provide reasonable and applicable solutions that were linked to the problems. These actions are more likely to be observed in experts' problem solving, however, question prompts in the present study supported the novice students to perform at a more sophisticated expert-like level.

The effectiveness of question prompts on promoting metacognitive thinking to support solving ill-structured problems supports the findings of previous research studies. Schoenfeld's (1985) study showed that students who are required to periodically stop during problem-solving and ask themselves metacognitive or reflective questions were more likely to focus on the process of problem-solving and have better performance in problem-solving (Schoenfeld, 1985). In the present study, students who received question prompts outperformed those who did not receive the prompts on making justifications for problem representation and providing rationales for problem solutions. Question prompts directed students' attention to explaining their thinking process and justifying their decision making more explicitly. In solving ill-structured problems, monitoring the problem solving process, and consistently providing justifications for the reasoning and decision making are critical for improving the problem situations. But these metacognitive processes are normally very implicit or skipped by novice problem solvers. Making these implicit processes explicit helps problem solvers internalize problem solving knowledge and transfer it to different problem situations (Salomon, 1987).

The present results suggest question prompts promoted both students' problem representation and solution seeking. However, it is very interesting that the main effect of question prompts was not significant on describing the problem symptoms in problem representation, nor on anticipating the consequence of the problem solutions. Means indicate that students performed fairly well on describing the symptoms of the problems across all the treatment groups. This result indicates that the question prompts were not critical for students in the process of describing the problem symptoms. According to Vygotsky's social development theory, learning activities that are oriented toward the development levels that have already been reached are ineffective and learning activities that are oriented toward developmental levels that are too far advanced for the learners' potential ability also are not effective (Vygotsky, 1978). In the present case, describing the problem symptoms only required students to state the superficial factors in the problem scenario. Students across all the treatment groups might have already reached the desired learning level for stating factors from a problem scenario, thus question prompts were not significantly effective in improving students' performance in stating problem symptoms.

On the other hand, means for anticipating solution consequence suggest that students did relatively poorly in this process across all the treatment groups. The non-significance of question prompts on this problem solving variable indicates that the question prompts were not effective in supporting students to anticipate the consequences of their solutions. This process required students to evaluate their solutions and anticipate both positive and negative impact on problem situations. In order to perform well in this process, students needed to have adequate domain knowledge and metacognitive skills. However, most students in this study were novices in the domain of classroom management. Therefore, the non-significance might indicate that the developmental level of the task was too advanced for students' potential ability. Another possible explanation for this non-significance is that the question prompts did not ask students to evaluate their solutions and anticipate the consequence directly, which might lead to a lack of support in the evaluation process. More specific guidance might help students perform better on the solution evaluation component in problem solving.

Research Question 2: Does the use of synchronous online peer collaboration along with collaborative reminders have an effect on the process of solving ill-structured problems?

The statistical results showed that students who received online peer collaboration treatment in the problem solving process had higher mean scores than did those in other groups on all problem representation components, including the number of problems represented, describing the problems, defining the goal of the problems, and providing justifications for problem representation. But the expected significant effects from the online peer collaboration treatment were not observed in the data. These results seem to contradict findings from previous studies that found that the interaction between collaborating peers would improve student performance in problem solving (Fawcett & Garton, 2005; King, 1991; Webb & Farivar, 1999; Uribe, Klein, & Sullivan, 2003). Fawcett and Garton (2005) found students performed better in well-structured problems when they collaborated with their partners. Uribe et al. (2003) used synchronous computer-mediated collaboration on ill-structured problem-solving tasks, and found participants in CMC performed significantly better than did participants working alone in terms of quality and time.

Ge and Land's (2003) study asked students to collaborate with each other in solving ill-structured problems in a face-to-face learning environment. Their results indicated that peer collaboration did not significantly impact problem solving process at either the overall level or univariate levels. The results of the present study are consistent with Ge and Land's findings, although the collaborations were conducted via computer-mediated communication instead of face-to-face communication. Ge and Land pointed out that time constrains and the short treatment period could be a possible reason for their non-significant findings. In the present study, time constrains also existed in the experiment. Compared to the other studies, the present study had a relatively short experimental time period. Students navigated the learning module and completed the problem solving tasks in one to two hours. The effective collaboration time on the problem solving tasks was even shorter. For effective peer collaboration, students need to establish an initial relationship for collaboration first and then construct the knowledge for problem solving (Johnson, Johnson, & Smith, 1991; Zhang & Ge, 2005). Tuckman suggested that collaboration team growth is a sequential and developmental process (Tuckman, 1965). Therefore, time has significant impacts on team dynamics and team performance (Gersick, 1988; Zhang & Ge, 2005). To develop effective peer collaboration, sufficient time needs to be ensured. However, during the one to two hour period of the experiment in the present study, there might not have been sufficient time for beneficial peer collaboration to develop.

Another explanation might be a lack of experience with peer collaboration in the problem solving process. All students in this study were new to the study's learning environment. Although at the beginning of this study the animation clips introduced the functions and tools in the learning environment and asked students to practice using these tools, students might still not have been familiar with how to discuss with their partners via computer-mediated communication. From field observations, a few students appeared to have computer anxiety and technology challenges in using the MSN Messenger tool during their discussion, thus they dropped out of discussion with their partners quickly and chose to work on the tasks individually. Also, all participants were selected from different classes where they had not received any training on how to use synchronous online discussion to collaborate with their partners and students might not know the strategies for effective collaboration. In the learning module of this study, collaboration reminders only reminded students to discuss the case with their partners. These reminders did not provide detailed strategies to support students' discussion. Therefore, although students may have been involved in the discussion with each other, due to the lack of previous experience with collaboration, particularly in the online learning environment, their discussions may not have been sufficiently helpful for analyzing the problem scenario and seeking solutions to improve the problem situation. In future studies, pre-treatment collaboration training and providing strategic collaboration prompts during the treatment might better support students' collaboration in the problem solving process.

Moreover, the present study was conducted in a controlled experimental environment. Compared to authentic problem solving situation, students in this study might not have seen the importance and the need for the online peer collaboration. From the field observations, many students tended to rush through the research procedures. When they were asked to discuss with their partners, their discussions were more likely to fulfill the experimental requirement rather than support each other on the critical thinking and reasoning in the problem solving. Without having an affirmative attitude toward and putting effort into the discussion, the peer collaboration might not have had adequate effects on the problem solving process.

Research Question 3: Does the use of synchronous online peer collaboration combined with procedural and metacognitive question prompts have an effect on the process of solving ill-structured problems?

Although the present study hypothesized that the question prompts can moderate the online peer collaboration to improve students' problem solving performance, the results did not show significant effects of the interaction between question prompts and online peer collaboration on the process of solving ill-structured problems. This finding was not consistent with previous studies on moderating peer collaboration. Zhang and Peck (2003) found that structuring and moderating group collaboration had significant positive effects on solving both well-structured and ill-structured problems (Zhang &

Peck, 2003). In their study, the moderation was applied to the collaboration groups through human moderators who were the instructors or trained students. Van Drie et al. (2005) found that procedural facilitation by way of using external representation guidance would help students' collaboration in writing tasks (van Drie, van Boxtel, Jaspers, & Kanselaar, 2005). Choi et al. (2005) tested the effects of providing externalized online guidance (computer-based question prompts) on generation of effective peer questioning in small group discussion. They found these prompting scaffoldings were useful in increasing the frequency of student questioning behavior during collaboration, but they did not find significant differences in the quality of students' questioning (Choi, Land, & Turgeon, 2005). Interestingly, Ge and Land's (2003) study revealed similar findings as the present study on the interaction of question prompts and peer collaboration. Their quantitative results showed that the main effect of the interaction was not significant at the multivariate level. At the univariate level, the effect of the interaction was significant only on problem representation, but not on the other processes of solving ill-structured problems. In their experiment, the peer collaborations were in a face-to-face environment. In the present study, the main effect of interaction was not significant at either the overall or univariate levels. This result partially supports Ge and Land's study although the present study used computer-mediated communicate to support peer collaboration. It should be noted that both the present study and Ge and Land study had shorter time for problem solving than would be found in most authentic settings.

There are some possible reasons that may have led to the non-significant results. First, the question prompts were designed for facilitating the problem solving procedure and promoting students' metacognition during problem solving. However, the online peer collaboration was intended as a means for collaboration during constructing knowledge, developing argument, and solving problems. Novice students in this collaboration process need specific guidance in order to collaborate with each other effectively (Zhang & Peck, 2003). The problem solving procedural prompts and metacognitive prompts might not be sufficient to promote online peer collaboration. Therefore, more specific collaboration question prompts might need to be designed to support the collaboration process. This type of question prompt might direct student peers to develop critical thinking and promote argumentation during the collaborative problem solving process. Second, compared with human moderation, the question prompts lacked flexibility in supporting different student groups. The diversity among groups brings different specific needs for collaboration support. Also, when student peers were guided by the web-based question prompts, they could not really interact with the moderator, that is, the question prompts, whereas in human-moderated situations students can interact with moderators to get suggestions and feedback. Therefore, when designing the collaborative question prompts, the researchers might need to hold flexibility and interaction in consideration. Moreover, the students in the collaboration with prompts group received both collaboration and question prompts, and were asked to discuss each question with their partner and answer the questions. Therefore, they spent the longest time working on the case study, although other groups were asked to review extra materials after they completed the case study. The students in this group might have had increased fatigue from the case study compared to other groups. The possibility of increased fatigue might have decreased their motivation and effort for the collaboration, thus decreasing the possible interaction of collaboration in the problem solving process.

Exploratory Findings

While the MANOVA and ANOVA results responded to the research questions, there also are some interesting findings from the correlation results. Results of the correlation analyses indicate that the problem solving variables were significantly correlated with each other. More specifically, the correlation pattern was strong among problem representation variables, as well as among problem solution variables. There were moderately strong correlations between representation and solution variables. Interestingly, the justification variables and rationale variables also showed moderately strong correlations with other problem solving variables. These results provide evidence to support the redefined IDEAL model for ill-structured problem solving. First, the results suggest that the IDEAL problem solving processes are linked to each other. They are in a bounded system. These findings supported Bransford and Stein’s discussion that stressed all the IDEAL components work together in a problem solving process (Bransford & Stein, 1993). A person who has high problem identification skills is more likely to perform well on problem goal defining and solution seeking. Moreover, the results suggest that justification and evaluation are important processes in problem solving. Justification and evaluation processes reflect the problem solver’s metacognitive skills. The strong correlations between these metacognitive variables and problem solving components provide evidence that metacognition is critical for solving ill-structured problems. In the problem solving process, consistent monitoring and justifications for reasoning and decision making will increase the quality and clarity of the problem solving.

Implications

The results in this study support some findings from previous research and also suggest some interesting new findings different from the previous research discussed in the earlier sections. A number of implications can be drawn from this study for instructional designers, educators in web supported environments, and educational researchers.

Implications for Instructional Designers

First, the findings of this study provide evidence that question prompts can not only facilitate the problem solving procedure, but also promote students' metacognitive skills in solving ill-structured problems. Both procedural knowledge and metacognitive knowledge are critical for solving ill-structured problems. Therefore, when instructional designers are planning problem solving activities in their instruction, especially web-based instructions, they need to consider using both procedural question prompts and metacognitive question prompts as a scaffolding strategy. The lack of face-to-face communication between students and teacher in web-based learning environment means specific supports are needed in the problem solving activity. Question prompts have the potential to function as "cognitive partners" to facilitate students' reasoning and decision making in solving ill-structured problems. Furthermore, the question prompts should be designed to address each component in the problem solving, such as problem identification, goal defining, providing rationale for representation, seeking solution, quality of solution, solution justification, and anticipating the solution consequences. Since the students did relatively poor on anticipating solution consequences in this study and the effects of question prompts were not significant on this variable, special attention should be given to guiding students to evaluate their solution and anticipate the consequences. Specific guidance is needed to direct students' attention to the evaluation process.

Second, the non-significant results of the online peer collaboration and the interaction of question prompts and collaboration also suggest some implications for instructional designers. When designing web-based instructions, collaboration can be an effective strategy, however, sufficient time needs to be allowed for each partner to elaborate their thinking process. A short period of online discussion might not provide enough support to improve their critical thinking in learning activities. The instructional designers also should consider the need for training students to help them get familiar with the online discussion environment and gain some collaboration experience gradually. In this way, students can develop their skills and strategies for online peer collaboration without computer anxiety and technology challenge. Furthermore, some supportive tools, such as strategic collaboration prompts, can be integrated into the learning environment to provide flexible guidance for online peer collaboration. However, these tools need to incorporate the specific strategies for online peer collaboration in order to improve the quality of collaboration.

Implications for Educators in Web-Based Learning Environment

The findings from this study also have some implications for educators who teach in a web-based learning environment. It is important for teachers and students involved in a web-based learning environment to understand the nature of the environment. Due to the lack of face-to-face communication, direct guidance and monitoring from teachers could be restricted in the web-based learning environment. Therefore, teachers should keep this in mind and help students develop some self-reminding and self-monitoring strategies in the learning activities. In complex learning activities, such as problem solving, these strategies may support students to analyze the case more deeply and critically. Otherwise, novice learners might remain at only a superficial level.

Implications for Educational Researchers

The results of this study suggest some implications for educational researchers interested in conducting educational research in the field of technology supported learning and collaborative learning. First, the correlation results from this study provide evidence to support the redefined IDEAL model for solving ill-structured problems. The IDEAL model for solving ill-structured problems is more complex than for well-structured problems. Educational researchers can apply the redefined model to support their studies and design new interventions in the field of problem solving. Second, inter-rater reliability indicated that the problem solving scoring rubric in this study had a fairly high capacity to capture the characteristics of ill-structured problem solving. Since this scoring rubric is not domain specific, it can be used in different knowledge areas. Therefore, this scoring rubric may be used in future problem solving studies to measure problem solving performance. Third, in the present study, the researcher considered integrating multimedia technology, such as meaningful pictures and animation clips, in the learning environment. These multimedia materials can not only provide learners a visually pleasing environment for learning, but also explain the procedures clearly and present the case scenarios authentically. Therefore, when educational researchers are designing technology related studies, they should consider incorporating appropriate multimedia. In addition, the researcher in this study conducted a front-end risk analysis to consider potential challenges. This strategy helped the present study to be conducted smoothly and avoided many side factors that can impact the study results. For example, to prevent the technology failure, test and retest were used on both the database server and research website. To prevent disturbance caused by time differences among groups, extra learning materials were added for groups that needed shorter time to complete the study. Also, to prevent database failure, the research data were backed up after every experiment section. Future studies also should include some risk analyses before the data are collected.

Limitations of the Study

This study has some limitations. First, all the participants in this study were pre-service teachers recruited from a college of Education. Most did not have actual experience solving ill-structured classroom management problems. Therefore, they might not have fully understood the urgent need for solving these problems. In contrast, in-service teachers will likely have experienced many classroom management problems, and may be more interested in solving the classroom problems than are pre-service teachers.

Second, the major incentive for students to participate in this study was extra credit in their classes. However, the quality of their performance was not associated with the credit received. Therefore, although they participated in the study, they might not have put their best efforts toward completing the learning tasks. The attitude and effort exhibited by the students toward the problem solving tasks in the collaboration group might have been particularly limited and they might have rushed through the learning module. Third, the present study was conducted in a two-hour time period. This time period may have been insufficient for most students to elaborate their thinking process. In particular, novice problem solvers need a longer period to work on a complex ill-structured problem solving task. The time constraint might partially explain why the collaboration treatment did not show significant effects on problem solving. Students in collaboration groups need sufficient time to process the information and contribute to the knowledge construction in the online collaboration. Furthermore, this study considers only quantitative data. Qualitative data analysis might facilitate more in-depth understanding of how students solve problems, how students interact with their online partners, how the question prompts influence students' collaboration, and how students perceive the question prompts treatment and online peer collaboration treatment in the problem solving.

Directions for Future Research

From the implications and limitations of the present study, some suggestions emerge for future research. First, peer collaboration needs moderation and guidance, which potentially can be provided via question prompts. In future studies, strategic collaborative question prompts should be designed to moderate the online collaboration process and researchers should investigate the effects of such strategic collaborative question prompts during the peer collaboration for ill-structured problem solving.

Second, since the procedural and metacognitive question prompts produced no measurable effect on students' evaluation of their solutions or anticipation of the consequences of their solutions, some more specific question prompts that address the evaluation and anticipation process should be designed. Such question prompts might better support students to evaluate their solutions, assuming they are designed to support students within their zone of proximal development. Future research should address the effect that specific evaluation prompts have on solving ill-structured problems.

Third, qualitative studies for analyzing the effect of question prompts on peer collaboration for problem solving can be conducted to bring more in-depth investigations. Qualitative approaches may include components such as content analysis of online discussion, interviews, field observations, and open-ended surveys.

Fourth, this study used pre-service teachers as research samples. These samples might have introduced some limitations to the study such as willingness and attitude for problem solving and collaboration, time constrains, and so on. Although the present study considered many aspects and was designed to create an authentic environment for students to experience "real-world" problem solving, as Kozma (2000) discussed, researchers should go beyond these limitations (e.g., time constrains, convenience sample, etc.) and scale up educational technology research and development (Kozma, 2000). Future studies should consider using participants from authentic settings related to the domain area. For example, in the classroom management domain, future studies may duplicate the present study with in-service teachers as research participants. Attempts toward authentic and immediately relevant matching of subjects and problem solving topic might result in increased generalizibility of the research results.

Summary

The current study investigated the effects of question prompts and online peer collaboration on solving ill-structured problems. The results indicate that procedural and metacognitive question prompts can provide effective scaffolding for solving ill-structured problems. However, significant effects of online peer collaboration were not observed. This study supported some previous research on using question prompts as a scaffolding strategy to support problem solving. Further, these findings support a redefined IDEAL problem solving model for solving ill-structured problems.

The findings of this study provide empirical support that question prompts can be integrated into the web-based learning environment to support learners in complex cognitive activities. The findings also suggest that some necessary guidance needs to be provided for online peer collaboration. Otherwise, the effect of online collaboration might be limited or non existent. Findings of this study can inform instructional designers in designing effective web-based instructions. These findings also can provide guidance for future educational research on problem solving scaffolding and online collaboration.

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APPENDIX A

DEMOGRAPHIC QUESTIONNAIRES

Demographic Information: **Study Number: __________**

1. Age:_____________

2. Sex: ___Male ___Female

3. What is your ethnicity?

___African American / Black ___American Indian or Alaska Native
___Asian ___Native Hawaiian or Pacific Islander
___Hispanic/Latino ___White
___Other

4. What is your major? ______________________

5. Year in School:

___Freshman ___Sophomore ___Junior ___Senior ___Graduate

6. How many college courses have you had in the following areas? (Including this semester)

Educational Psychology: ____________
Instructional Technology: ____________
Classroom Management: ____________
Other Education: ____________

7. How much do you know about how to manage a classroom effectively?

1-----2-----3-----4-----5-----6-----7
Not Confident Very Confident

8. How confident are you that you can accomplish each of the following:

1-----2-----3-----4-----5-----6-----7
Not Confident Very Confident

_____ a. I can successfully use computers to do things related to my classes.
_____ b. I can successfully read information on a computer screen.
_____ c. I can successfully select important information from the web pages.
_____ d. I can successfully use chat tools to communicate with my classes.

9. How confident are you that you will:

1-----2-----3-----4-----5-----6-----7
Not Confident Very Confident

_____ a. Successfully complete all activities with my writing skills?
_____ b. Successfully express my ideas clearly with my writing?
_____ c. Focus on the most important information in my writing?
_____ d. Successfully write a paper with flow thoughts?
_____ e. Construct a good argument on the writing tasks?

APPENDIX B

VIDEO SCRIPT FOR PROBLEM SCENARIO

Video Script for Problem Case Scenario

You are an expert in classroom management practices and have been asked by the principal of Roosevelt middle school to meet with a Mrs. Green, a first year teacher who has been experiencing problems with her ninth grade Algebra class. While in her class, you observe the following exchange between Mrs. Green and her students.

Your task is to send Mrs. Green an email that summarize your ideas regarding the problems in her classroom and discuss with her about effective classroom management strategies.

First Vignette

(Mrs. Green is introducing the concept of sets to her class.)

Mrs. Green: So today we are talking about groups. We all talk about groups all the time. We talk about groups every day in our lives. We talk about a group of football players. We talk about a deck of cards. We talk about a dozen eggs. What are some other groups we talk about?

Jimmy: (yelling out) A school of fish!!!

Mrs. Green: A school of fish is right, Jimmy. (Mrs. Green walks to the chalkboard and writes Jimmy's name). But, what is our rule?

Jimmy: We're supposed to raise our hand and wait to be called on.

Mrs. Green: That's right.

Mrs. Green: Okay, so a school of fish is an example of group. Now who knows what these groups are called in algebra? (Kisha raises her hand) Kisha?

Kisha: They are called sets. And I don't think it is fair that you put Jimmy's name on the board.

Mrs. Green: Jimmy’s name is on the board because he violated one of our rules.

Kisha: But it is not fair because it's not like he was talking to another student and disturbed the entire class.

Mrs. Green: Yes, but if he is talking out of turn, it could be just as distributive as he is talking to another student out of class. And we really need to maintain order. Besides, all I did is write his name on the board and he still has to get another mark and another mark after that before he gets to see the principle. So he is fine as long as he doesn’t break any more rules. Okay?

Kisha: I still don't think it is fair.

(Mrs. Green walks to the board and writes Kisha's name directly under Jimmy's name. All the students look upset.)

Mrs. Green: I will not tolerate breaking rule in this class. If you are talking out of term, you are breaking the rules. I have five simple rules. If you break a rule, I will write your name on the board. If you break a rule twice, I will put a line by your name. You know this and we talked about this since the first day of class. If you break the rule again, I will put another line by your name and only then do you have to go to the principal and get an "F" for the day. Have we talked about this before? Okay.

Mrs. Green: Now, who can tell me, what is a subset? Jason?

Jason: A subset is a set within a larger set.

Mrs. Green: That's right. A subset is a set within a larger set. Now I noticed you had to take earphones out of your ears to say that, Jason. (Jason had his earphones on and he takes them off.) What is one of my rules about earphones during the class? (Mrs. Green writes Jason's name on the board.) Do you remember the rule? Okay, no earphones while we are having a discussion in class.

Jason: I'm sorry Ms. Green!

Mrs. Green: Thank you for your apology.

Mrs. Green: Now we are going to learn a little more about sets, so what I'd like you to do – are you all paying attention? – Everybody, please, turn to page 243 in your books and complete exercises 7.1, 7.2, and 7.3. Then go to page 250 and do exercises 7.7-7.9. These exercises will help you learn more about sets.

(Johnny raises his hand and asks.) Johnny: Do we have to do all of them?

Mrs. Green: Yes, Johnny. You do have to do all of them. I noticed you raised your hand, that was good, but you need to wait 'til I called on you. Okay? (She writes Johnny's name on the board. The whole students look upset.)

Kisha: You are the worst teacher I have ever had.

Mrs. Green: Well, Kisha, I think when you get older, you will find that I was helping you learn discipline. (She put a mark by Kisha's name on the board). Okay, everybody, noses in your books, and let's learn about sets.

Second Vignette

Melissa: (whispers to Andrea) Do you have a pencil I can borrow?

(Mrs. Green walks to the board and writes Melissa's name under Kisha's).

Melissa: Hey, why did you write my name on the board? I was just trying to borrow a pencil.

Mrs. Green: You spoke out of turn and did not raise your hand.

(Mrs. Green puts a mark by Melissa's name)

Melissa: Well, if I'd raised my hand, Andrea wouldn't have known that I needed a pencil. That's stupid.

(Mrs. Green puts a second mark by Melissa's name).

Mrs. Green: That's two marks Melissa.

(Melissa raises her hand, but Mrs. Green ignores her.)

Mrs. Green: Please take this pass to the principal's office.

(Melissa gets up, grabs the pass, and leaves the room).

Mrs. Green: Okay, let's get back to where we were. (By now the class is completely distracted. They lose focus for the rest of the hour).

APPENDIX C

QUESTION PROMPTS FOR PROBLEM SOLVING

Question Prompts for Problem Solving

Your task is to send Mrs. Green an email that summarize your ideas regarding the problems in her classroom and discuss with her about effective classroom management strategies. The following questions are designed to assist you organize your thoughts and writings in terms of formulating a formal email to Mrs. Green.

Feel free to refer to the resource pages to assist you as you complete this task.

1. What is the major problem in Mrs. Green’s class? Please give some specific examples of this problem. Why do you think it is a problem in her class?

2. What type of classroom management problem is it? Why do you categorize this problem?

3. What are some other problems in Mrs. Green’s class? Please give some specific examples of these problems. Why do you think they are problems in her class?

4. What types of classroom management problems are they? Why do you categorize these problems?

5. Have you encountered similar problems in your past learning or teaching experiences? How do those problems relate to the problems in Mrs. Green’s class? How were those problems solved?

6. What is your solution to the major problem that you identified? Please give some specific examples for the solution. Why do you think your solutions will work for this problem in this class situation?

7. What are your solutions to the other problems that you identified? Please give some specific examples for the solutions. Why do you think your solutions will work for these problems in this class situation?

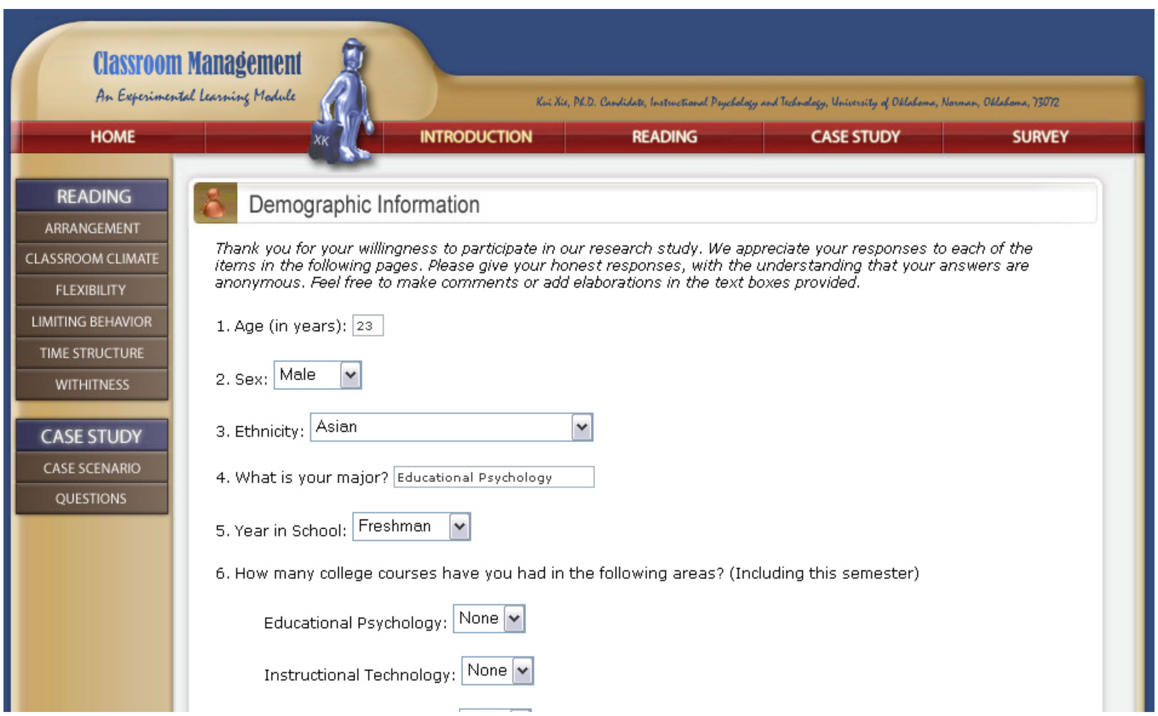
APPENDIX D

WEB-BASED LEARNING ENVIRONMENT

Screen Shots of Web-Based Learning Environment

1. Introduction Page

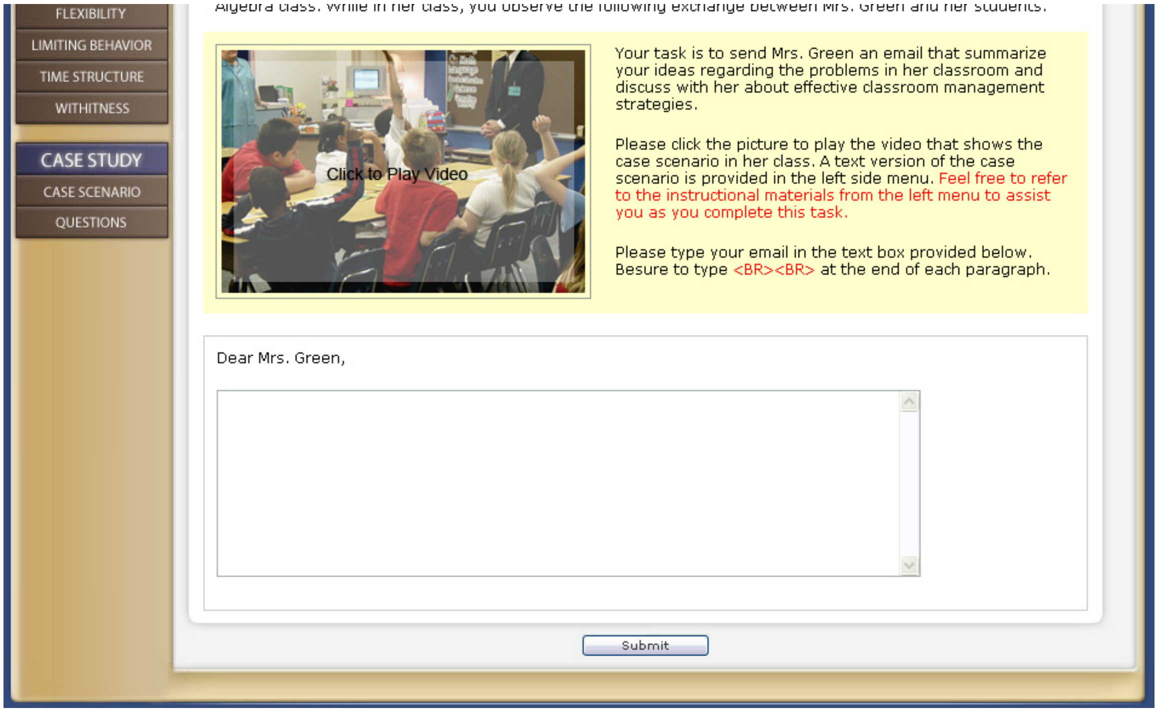
2. Demographic Survey



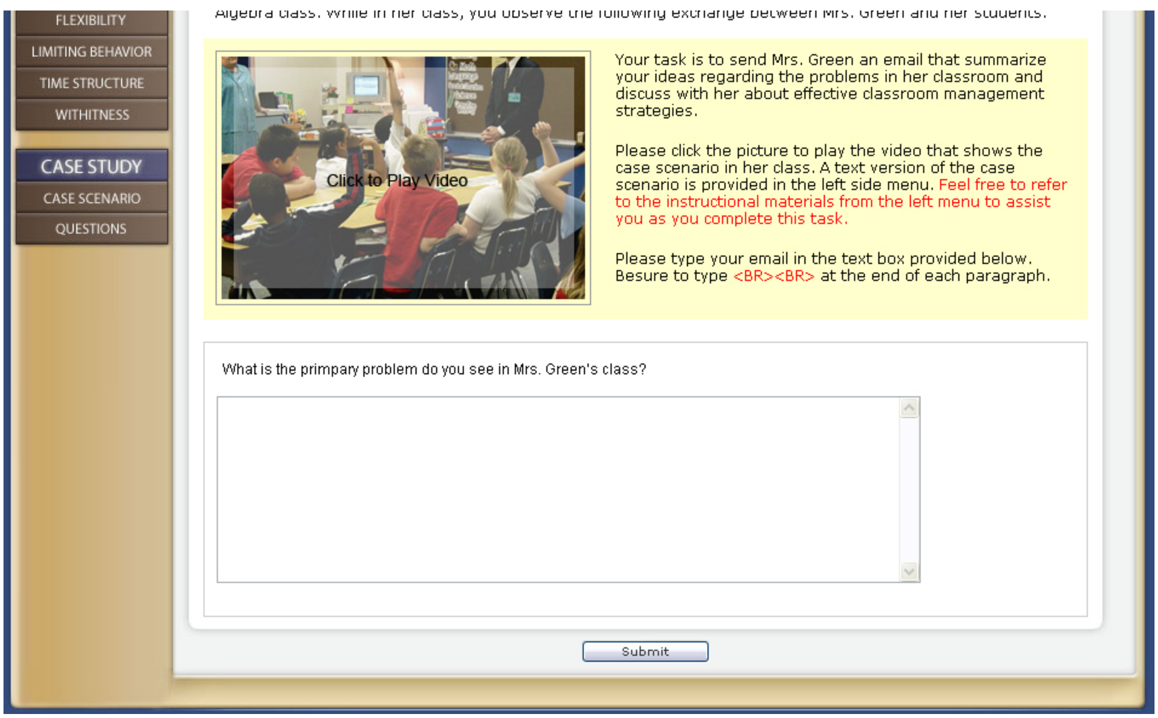
3. Instructional Materials

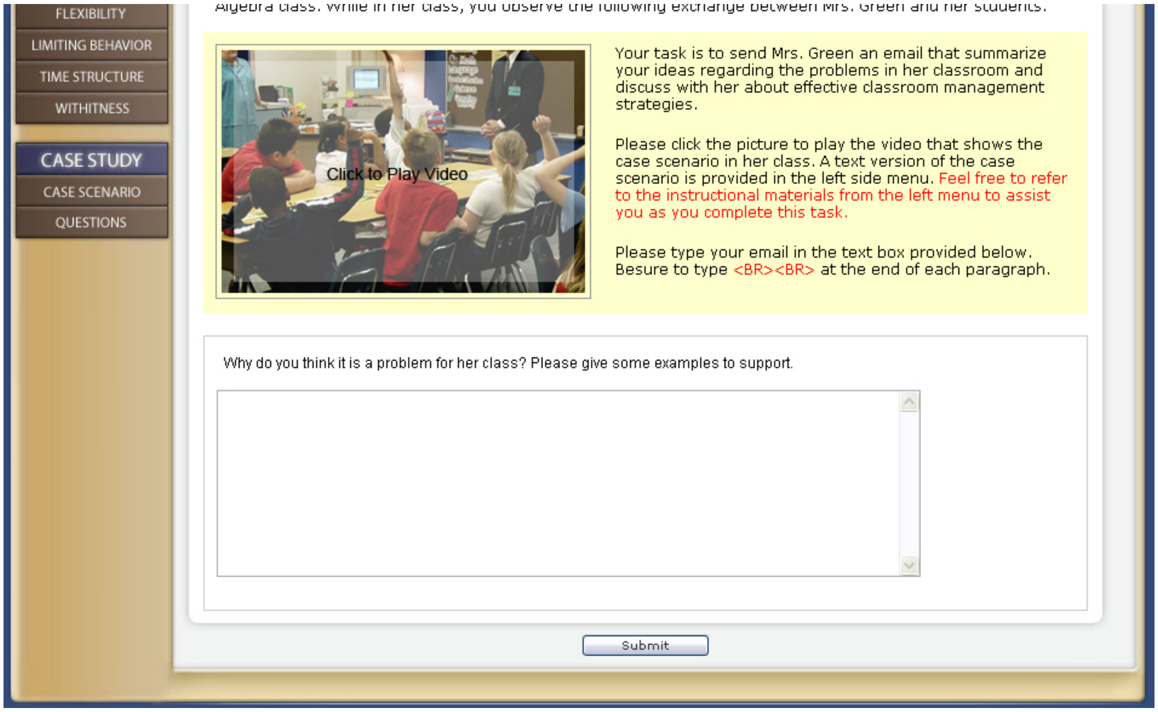
4. Case Study

5. Problem Response in Control Group

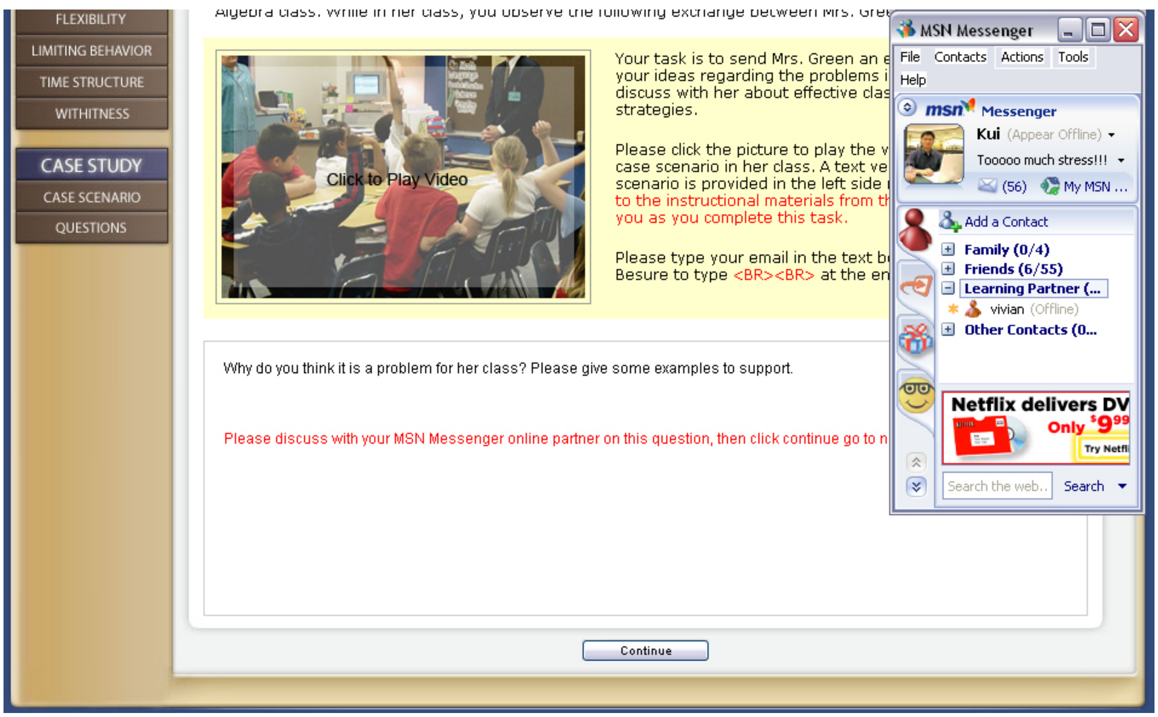


6. Problem Response in Prompt Condition





7. Problem Response in Collaborative with Prompt condition.



APPENDIX E

SCORING RUBRIC FOR PROBLEM CASES

Scoring Rubric for Problem Cases

<u>Problem Representation:</u>

1. **Identify the Problem – Number of Problems (5)**
2. **Describe what are the problems (9)**
   - Describe the symptoms of the problem with detailed examples – 9.
   - Describe the symptoms of the problem without examples – 6.
   - Infer the problem without describe it – 3.
   - Not describe the problem – 0.
3. **Define the Goal – Define what the goal of the problem solving is (9)**
   - Define the Goal of the problem or categorize the problem with detail explanations – 9.
   - Define the Goal of the problem or categorize the problem – 6.
   - Infer the goal of the problem or categorize the problem – 3.
   - Not define the goal or categorize the problem – 0.
4. **Provide Rationales for Problem Representation –** Describe why they are problems: **(9)**
   - Provide rationales for problem representation or explain the situation with detailed examples – 9.
   - Provide rationales for problem representation or explain the situation without examples – 6.
   - Infer rationales for problem representation – 3.
   - Not provide rationales for problem representation – 0.

<u>Suggest Solution for Problems:</u>

1. **Make Suggestions for Solution – Number of Suggestions**
2. **Quality of Solutions (9)**
   - The solutions are linked to the problems that have been identified & with detailed examples – 9.
   - The solutions are linked to the problems that have been identified, but with unclear descriptions – 6.
   - The solutions are not linked to the problems that have been identified OR the solutions are not appropriate for the solving the problems – 3.
   - No solution has been suggested – 0.
3. **Provide Rationales for Solutions (9)**
   - Provide explanations to support solutions with explanations – 9.
   - Provide explicit support for solutions – 6.
   - Provide implicit support without examples – 3.
   - List solutions without support – 0
4. **Anticipate Consequences of the Solutions (9)**
   - Describe the consequence of the solutions explicitly– 9.
   - Infer the consequence of the solutions – 6.

- Describe the consequences that are not linked to the problems or not reasonable for the problem situation – 3.
- Not describe the consequence of the solutions – 0.

Note: This rubric was used for scoring students' final reports.

Scoring Rubric with Detailed Examples

<u>Problem Representation:</u>

1. **Identify the Problem – Number of Problems (5)**
   Count the number of problems that have been identified by the subject. If the subject described some problems differently but they belong to the same type of problem, they should be counted as one problem.

2. **Describe what are the problems (9)**
   - Describe the symptoms of the problem with detailed examples – 9.

   "Entering the lesson that I observed, the students seemed to have a positive relationship with each other and with you; however, as the lesson progressed this seemed to deteriorate." "*In the current context, you went directly to placing Jimmy's name on the board for answering a question you had asked. This changed the climate immediate" – Expert 2*

   - Describe the symptoms of the problem without examples – 6.

   "I believe you are spending too much class time talking about the rules that were previously established." – Expert 1

   - Infer the problem without describe it – 3.

   If subjects jump to giving suggestions without describing the problems, we can infer they have problem representation process implicitly.

   - Not describe the problem – 0.

3. **Define the Goal – Define what the goal of the problem solving is (9)**
   After the problem symptom has been described, an export problem solver will define the goal of the problem solving and identify the root of the problem. For example, if the problem symptom is students are in bad mood and cannot concentrate on their study, the goal of the problem solving might be to create a positive Classroom Climate or alternative goal might be increasing Withitness. The subject doesn't have to use the exact word as the reading materials has.

   - Define the Goal of the problem or categorize the problem with detail explanations – 9.

   "The primary classroom management problem that I see, I would classify as related to classroom climate. At this time it does not seem to be too bad; however, if things continue in this way the climate could get worse. By climate I mean the attitudinal relationship between teacher and student." – Expert 2

   - Define the Goal of the problem or categorize the problem – 6.

   "The problem in your class is limiting behavior problem. There seems to be no solid rationale for the rules, they are just there for the sake of rules." – Student 3

- Infer the goal of the problem or categorize the problem – 3.

"I believe that you are too strict with your students." – Student 2 (Infer Flexibility Problem)

- Not define the goal or categorize the problem – 0.

4. **Provide Rationales for Problem Representation –** Describe why they are problems: **(9)**
   - Provide rationales for problem representation or explain the situation with detailed examples – 9.

   "This changed the climate immediate, as evidenced by next student using her chance to speak as an opportunity to complain about the unfairness of this action. The use of this strategy for behaviors that are in fact instructionally desirable (you want students engaged and answering your questions) can lead to lower rates of participation." – Expert 2

   "Rules are should be the focus of the class as that takes away from the pleasantness of the classroom climate, makes you and your class seem inflexible and, most importantly, has you wasting time on rule discussion and enforcement." – Expert 1

   - Provide rationales for problem representation or explain the situation without examples – 6.

   - Infer rationales for problem representation – 3.

   - Not provide rationales for problem representation – 0.

Suggest Solution for Problems:

1. **Make Suggestions for Solution – Number of Suggestions**
2. **Quality of Solutions (9)**
   - The solutions are linked to the problems that have been identified & with detailed examples – 9.

   "If you keep the existing rule, provide students with a reminder of the expected behavior, and either ignore appropriate answers that were not properly given (did not raise hand, did not wait for teacher recognition) and call on a student who has followed the rule, or use positive practice, that is have the student who failed to raise his hand, stop, raise his hand, then call on him and have him provide his answer." – Expert 2

   "I would recommend that, in addition to making sure your most important rules are posted in the classroom, which reconsiders the roll of your current enforcement of rules on the climate of your classroom." – Expert 1

- The solutions are linked to the problems that have been identified, but with unclear descriptions – 6.

"Maybe it would be good for you to re-think the purposes behind your rules and try to make them address problems that really are problems." – Student 3

"I would suggest some added flexiblity in your own approach to the student-teacher relationship." – Student 4

- The solutions are not linked to the problems that have been identified OR the solutions are not appropriate for the solving the problems – 3.

"Add more fun and entertainment to the classroom." – Student 2

"The environment needs to be more positive." – Student 2

- No solution has been suggested – 0.

3. Provide Rationales for Solutions (9)

- Provide explanations to support solutions with explanations – 9.

"Students of your age level can certainly learn when some calling out is apropriate and when it is not. The rule about headphones can be conveyed by pointing to the ears or the rules on the walls, rather than making a big deal about them verbally. You were the only person bothered by the use of headphones, so why did the whole class have to be interrupted about them? Think about when to interevene verbally, which interrupts the class, and when to use non-verbal signals to get students to follow rules. When students whisper to one another about borrowing a pencil, they are not bothering other people either. That is what we call fleeting minor behavior that makes more sense to ignore than verbalize to the whole class." – Expert 1

- Provide explicit support for solutions – 6.

"It is very hostile and negative right now. It is not a good environment for learning situations." – Student 2

- Provide implicit support without examples – 3.

"In this way you encourage desirable participation and discourage inappropriate participation." – Expert 2 (Providing rationale to support by anticipate consequences of the solution.)

- List solutions without support – 0.

4. Anticipate Consequences of the Solutions (9)

- Describe the consequence of the solutions explicitly– 9.

"Such practice may help make hand raising become more routine and does not depend on the use of punishment." – Expert 2

"If you showed more flexibility then you might have students more willing to work, less willing to argue." – Expert 1

- Infer the consequence of the solutions – 6.

"This will help students be mindful of expectations." – Student 4

- Describe the consequences that are not linked to the problems or not reasonable for the problem situation – 3.

- Not describe the consequence of the solutions – 0.

Note: This rubric was used in the scoring training process. It was also used as the reference in the review process.

APPENDIX F

EXPERTS' REPORTS

Problem Solving Report from Expert One

Dear Mrs. Green,

Although I appreciate that you are trying to be consistent with your rules, I beleive you are spending too much class time talking about the rules that were previously established. You might be able to limit student behavior more effectively if you had the rules posted on the wall and could point to them rather than set up the circumstance for students to argue with you about the rule. Rules are should be the focus of the class as that takes away from the pleasantness of the classroom climate, makes you and your class seem inflexible and, most importantly, has you wasting time on rule discussion and enforcement.

I would recommend that, in addition to making sure your most important rules are posted in the classroom, that reconsider the roll of your current enforcement of rules on the climate of your classroom. If you showed more flexilbity then you might have students more willing to work, less willing to argue. I do not mean that you should throw your rules out, but sometimes calling out duirng instruction is not really a problem and sometimes it is a big problem. Students of your age level can certainly learn when some calling out is apropriate and when it is not. The rule about headphones can be conveyed by pointing to the ears or the rules on the walls, rather than making a big deal about them verbally. You were the only person bothered by the use of headphones, so why did the whole class have to be interrupted about them? Think about when to interevene verbally, which interrupts the class, and when to use non-verbal signals to get students to follow rules. When students whisper to one another about borrowing a pencil, they are not bothering other people either. That is what we call fleeting minor behavior that makes more sense to ignore than verbalize to the whole class.

Bottom line, you are wasting too much of the class' time on your need to control student behavior. The result is that the classroom climate is one of hostility between you and the students rather than one conducive to students wanting to learn. Use more non-verbal cues for rules, step out behind the podium to interact more with students, and work on creating a more learning-focused classroom rather than a classroom obviously focussed most on conforming to rules.

Comment [XK1]: Describe symptoms of time structuring problem.

Comment [XK2]: Define goals of the problem. Make suggestion – Post rule.

Comment [XK3]: Provide Rationale for problem representation.

Comment [XK4]: Alternative Solutions - Flexibility

Comment [XK5]: Anticipate consequences from solutions

Comment [XK6]: Provide Rationale for Solutions using specific examples.

Problem Solving Report from Expert Two

Dear Mrs. Green,

With my brief observation of your instruction and your students, I am pleased to report that I do not see any major classroom management problems. The major goal of effective classroom management is to foster student engagement in the lesson. Your students appeared to be attentive to your lecture and questioning, and were responsive to the questions. These are all positives.

The primary classroom management problem that I see, i would classify as related to classroom climate. At this time it does not seem to be too bad; however, if things continue in this way the climate could get worse. By climate I mean the attitudinal relationship between teacher and student. Entering the lesson that I observed, the students seemed to have a positive relationship with each other and with you; however, as the lesson progressed this seemed to deteriorate. The catalyst for this decline in climate was the approach you took to enforce the rules/behavior limits you had established. In particular, you seemed quite concerned about one rule, speak only after raising your hand and being recognized by the teacher. Although having such an expectation is fine, your method of enforcement created more problems than the students' speaking without being called on.

You implemented a common strategy, putting students' names on the board for a first violation, followed by check marks for subsequent violations. This can be an effective strategy if students have been reminded of the rule and have chosen to ignore it. In the current context, you went directly to placing Jimmy's name on the board for answering a question you had asked. This changed the climate immediate, as evidenced by next student using her chance to speak as an opportunity to complain about the unfairness of this action. The use of this strategy for behaviors that are in fact instructionally desirable (you want students engaged and answering your questions) can lead to lower rates of participation.

Two things that could have been done to address the problem behavior without the negative side effects would be: (1) modify your rule. If students speak appropriately to a question that you have raised, do not consider this a problem. Make inappropriate, off-task speaking, whether students have raised their hands or not, a rule violation. In this way you encourage desirable participation and discourage inappropriate participation. (2) If you keep the existing rule, provide students with a reminder of the expected behavior, and either ignore appropriate answers that were not properly given (did not raise hand, did not wait for teacher recognition) and call on a student who has followed the rule, or use positive practice, that is have the student who failed to raise his hand, stop, raise his hand, then call on him and have him provide his answer. Such practice may help make hand raising become more routine and does not depend on the use of punishment.

I hope these ideas prove helpful.

Comment [XK1]: Define the Problem

Comment [XK2]: Further Explain Problem Defining

Comment [XK3]: Describe Problem Symptoms.

Comment [XK4]: Go deeper to analyze the root of the problem.

Comment [XK5]: Explain the problem representation with a detailed example.

Comment [XK6]: Describe other problem symptoms with an example.

Comment [XK7]: Provide rationales for problem representation with examples

Comment [XK8]: Solution One

Comment [XK9]: Describe and explain the solution which linked to the problem.

Comment [XK10]: Anticipate consequence and provide rationale.

Comment [XK11]: Solution Two with clear description.

Comment [XK12]: Anticipate consequence and provide rationale.