Xie, K., & Bradshaw, A. C. (2008). Using question prompts to support ill-structured problem solving in online peer collaborations. *International Journal of Technology in Teaching and Learning, 4*(2), 148-165.

Using Question Prompts to Support Ill-Structured Problem Solving in Online Peer Collaborations

Kui Xie
Mississippi State University
&
Amy C. Bradshaw
University of Oklahoma

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. They were asked to solve real-world ill-structured problems in a case scenario. The results revealed significant effects of 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 has implications for instructional designers and educators in designing collaborative learning activities with technology support.

Keywords: Online collaboration, Problem solving, Synchronous online discussion, Question prompts

INTRODUCTION

Web-based instruction has been gaining use in educational settings during the past several years and has brought many benefits to education (Horton, 2000). However, without face-to-face guidance, monitoring, and communication with the instructor or peers, students in these environments may experience difficulties, especially for learning tasks aiming to develop higher-order thinking skills, such as problem solving.

Kui Xie is an Assistant Professor in the Department of Instructional Systems and Workforce Development at Mississippi State University, MS. Amy C. Bradshaw is an Associate Professor in the Department of Educational Psychology at the University of Oklahoma, OK. Please contact Dr. Xie at: kxie@colled.msstate.edu

Two promising strategies for providing scaffolding for student problem solving are online peer collaboration and question prompts (Cheung & Hew, 2004; Ge & Land, 2003; Uribe, Klein, & Sullivan, 2003). Online peer collaboration refers to student peers collaborating on learning tasks via computer-mediated communications (CMC), in which students work in groups and interact with peers, mutually searching for understanding, solutions, or meanings, or creating a product. A successful peer collaboration needs appropriate moderation (Bernard, Rojo de Rubalcava, & St-Pierre, 2000; Xie, DeBacker, & Ferguson, 2006; Zhang, 2004). But 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 sufficient for all interaction groups. Alternative ways of providing moderation need to be considered. Research studies indicate that appropriately programmed computers may function as cognitive partners for learners by providing supportive question prompts during the learning processes (Salomon, 1987; Zellermayer, Salomon, Globerson, Givon, 1991). With the capacity of being a cognitive partner, question prompts might be able to provide scaffolding for students in online peer collaboration groups to solve ill-structured problems. However, little research has addressed the interaction of online peer collaboration and question prompts in solving ill-structured problems to understand the effects of these two scaffolding strategies for different problem-solving components.

SCAFFOLDINGS IN INSTRUCTION

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). The notion of scaffolded instruction was introduced in Vygotsky's Social Development Theory (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). 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.

ONLINE PEER COLLABORATION AND THE MODERATOR

Vygotsky 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. Students in a collaboration group work together in searching for understanding, meaning or solutions or in creating a learning 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). Under appropriate guidance and monitoring, peer interaction may also facilitate cognitive thinking and improve metacognitive skills for learning activities, such as solving ill-structured problems (Ge & Land, 2003). 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).

Successful online collaborations should be well moderated (Flannery, 1994). In a moderated discussion group the instructor or someone else watches over the exchange of messages. A good moderator has to both stand back and let the participants play the main role in the discussion and also intervene to guide the discussion into meaningful directions (Benfield, 2002; Horton, 2000). Instructors or trained students may assume a moderator's role in an online collaboration activity (Bernard, Rojo de Rubalcava, & St-Pierre, 2000). Structuring and moderating efforts on group work and the collaboration process in online forums may lead to stronger reasoning in both well-structured and ill-structured problem-solving tasks (Zhang & Peck, 2003). In addition, with moderator's guidance, students are more likely to perceive online discussion activity as a useful and valuable way to communicate and get information (Xie, DeBacker, & Ferguson, 2006).

QUESTION PROMPTS FOR SCAFFOLDINGS

Prompting students with appropriate questions is another effective strategy for scaffolding (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 to acquire a better understanding of the kinds of questions they should be addressing in learning and problem-solving practice. Question prompts provide a means to externalize mental activities that are usually covert (Scardamalia & Bereiter, 1985). They can be oriented more toward procedural guidance or more toward fostering metacognition.

Prompts designed for procedural guidance 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). Studies showed that question 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, et al., 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, et al., 1991). Furthermore, question prompts can provide one method for fostering self-monitoring, self-explaining, and self-evaluation and knowledge integration. Research shows that students who are required to stop periodically during problem-solving and ask themselves metacognitive 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, et al., 1991). Zellermayer (1991) believed that externally provided metacognitive 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).

COMPUTER SUPPORTED PEER COLLABORATION

Many researchers believed that a computer system could serve as a moderator in collaborative learning activities. Katz and Lesgold proposed a computer tutoring system – Sherlock II (Katz & Lesgold, 1993) including a collaborative learning component, which not only prompts students with suggestions, but also analyzes students' discussion content automatically to control the peer interaction (Katz, Aronis, & Creitz, 2000). Other projects, such as MEMOLAB (Dillenbourg, Mendelsohn, & Schneider, 1994) and Three's Company (Lin, 1993), also attempted to use artificial intelligence to support online collaborative learning. These systems emphasized the sophisticated techniques and the interface design to analyze the communication, control peer interaction, and manage the discussion process.

On the other hand, Scardamalia et al. argued that these systems are not only difficult to realize with high investment of time, cost, and human effort, they also may be heading in the wrong direction (Scardamalia, Bereiter, & Lamon, 1994; Scardamalia, et al., 1989). They proposed an approach for supporting collaborative learning using "procedural facilitation," in which all the decision-making processes are still made by learners, but computers provide guidance and suggestions to support their collaboration. Their proposed system – Computer-Supported Intentional Learning Environment (CSILE) 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). Choi et al. (2005) tested the effects of providing externalized online guidance (e.g., question prompts) on generation of effective peer-questioning in small group discussion. 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.

In problem-solving activities, well-designed prompts may guide the problem-solving process and promote metacognitive thinking and questioning (Ge & Land, 2004). But can they also direct students' peer collaboration and channel their interactions for better collaborating on problem solving? The purpose of this present study is to investigate the effects of online peer collaboration and question prompts 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. Specially, the following three research questions guided this study:

1. Does the use of question prompts have an effect on students' problem solving for ill-structured problems?
2. Does the use of synchronous online peer collaboration along with collaboration reminders have an effect on students' problem solving for ill-structured problems?
3. Does the use of synchronous online peer collaboration combined with question prompts have an effect on students' problem solving for ill-structured problems?

METHOD

RESEARCH DESIGN

This study used a 2 x 2 factorial experimental design to address the research questions. Two types of treatment were involved in the experimental design – question prompts and online peer collaboration. Dependent variables include two major components of problem solving: problem representation and problem solution, which are described in the scoring section.

Treatment 1. Question Prompts were designed to provide procedural and metacognitive scaffoldings for problem solving (Choi, Land, & Turgeon, 2005; Davis & Linn, 2000; Ge & Land, 2003). In the present study, all the subjects assigned to this treatment condition were provided with question prompts in pop-up windows, which include procedural guidance to help learners complete specific tasks and provided learners with specific procedural hints or suggestions that facilitate the completion of the tasks (Rosenshine, Meister, & Chapman, 1996), for instance, "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?" and reflection questions to foster self-monitoring, self-explaining, and self-evaluation in the problem-solving process, for instance, "Why do you think it is the major problem?", "Why do you think these strategies can help to solve the problems?" We believe these prompts will support students in their problem-solving activities. They may also provide guidance for their collaboration during problem solving. Students were asked to type their responses to these prompts.

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 experimental environment to allow learners to collaboratively solve the problems in the given instructional scenarios. Two subjects were put in each group for collaboration. A brief instruction and practice were provided to teach the subjects how to use the functions of MSN Messenger© required in this study. In addition, collaboration reminders were provided periodically to remind the subjects to discuss the problem case with their partners. An example of the collaboration 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."

The subjects were randomly assigned into different treatment groups or the control group by the experiment system automatically. The system also ensured that each group had an equal number of subjects. The four groups were (a) collaboration with question prompts, (b) question prompts only, (c) collaboration without question prompts, and (d) control group with neither question prompts nor collaboration.

PARTICIPANTS

The subjects in this study were 60 undergraduate students from a College of Education in a large South Central university, from instructional psychology and technology classes delivered in face-to-face settings. They were 86.7% Caucasian (n = 52) and 13.3% other ethnicity groups (n = 8). 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. All subjects were pre-service teachers who had basic understanding of lesson plan design, classroom management, and human psychology, and had already completed classes related to classroom management.

MATERIALS AND INSTRUMENT

Materials included a demographic questionnaire, instructional materials, and a case scenario that contains a number of ill-structured problems. All the materials were embedded in a multimedia enhanced website.

Demographic questionnaire. The demographic and prior knowledge questionnaire 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 questionnaire also included questions for classroom management confidence, computer and Internet skill confidence, and writing skill confidence. All these confidence questions were measured via a seven-point Likert-style scale.

Instructional materials. The instructional materials contained both classroom management knowledge reviews and instructions for technology use. The domain knowledge review materials included approximately 1500 words of text describing a number of classroom management principles, including classroom arrangement, classroom climate, flexibility, limiting behavior, time structuring, and withitness. They were adapted from Kauffman et al. (2005), which have been verified by classroom management domain experts. The instructions for technology use trained participants for using the tools and resources provided in the experiment site. The technology training included introduction to the environment, introduction to question prompts, and introduction to MSN Messenger. They were presented in three interactive animation clips.

Problem case scenario. 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.

PROCEDURE

The research sites were located in two rooms in a College of Education building. Subjects were invited to research sites in a scheduled lab session and were distributed evenly into these rooms. The research administrators were the investigator and a graduate student familiar with educational research data collection processes. They announced the start of the research and asked the subjects, 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 receiving the online peer collaboration treatment.

When the subjects logged in to the web-based learning system using an assigned ID number, they were presented with an animation clip introducing the learning environment. 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 subjects were given a case scenario and asked to identify and solve the instructional problems in the case. Subjects 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 1.

Table 1. Research Procedure

	Introduction	Instruction for Environment	Practice for Prompts	Practice for MSN	Pre Treatment Questionnaire	Learning Materials	Case Study		
							Case Scenario	Prompts	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.*

The research administrators facilitated the whole research procedure, and watched for and helped students who had technology difficulties, such as logging-in problems and internet-connection problems. In addition, 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 question prompts and the final reports were recorded into a database. These data were retrieved for scoring and analysis. The responses to the extra materials were not recorded or analyzed.

SCORING

Students' problem solving reports were scored using rubrics created by the researcher to assess the extent to which students identified problems and suggested solutions. The scoring rubric was based on the rubric used in Ge and Land's study (2003). Two domain experts were identified and invited to verify the scoring rubric. Both of them are professors in Educational Psychology who have more than 10 years of experience in teaching and research related to classroom management.

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 scoring rubric used in Ge and Land's study (2003), 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 (a) the number of problems, (b) description of the problem, (c) goal definition, and (d) justification for problem representation. Under problem solution, the rubric also specified four detailed criteria, including (a) the number of solutions, (b) quality of the solutions, (c) rationales for solutions, and (d) consequence anticipation. Then, another domain expert was asked to go through the learning module for the control condition using the same procedure used the first domain expert.

Table 2. Scoring Rubric for Problem Solving

Problem Representation:

1. **Identify the Problem – Number of Problems (5)**
2. **Describe what are the problems (10)**
   - Describe the symptoms of the problem with detailed examples – 10.
   - Describe the symptoms of the problem without examples – 6.
   - Infer the problem without describe it – 3.
   - Not describe the problems – 0.
3. **Define the Goal – Define what the goal of the problem solving is (10)**
   - Define the Goal of the problem or categorize the problem with detail explanations – 10.
   - 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: **(10)**
   - Provide rationales for problem representation or explain the situation with detailed examples – 10.
   - 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 (10)**
   - The solutions are linked to the problems that have been identified & with detailed examples – 10.
   - The solutions are linked to the problems that have been identified – 6.
   - The solutions are not linked to the problems that have been identified – 3.
   - No solution has been suggested – 0.
3. **Provide Rationales for Solutions (10)**
   - Provide explanations to support solutions with evidences or examples – 10.
   - Provide implicit support for solutions with examples listed – 6.
   - Provide implicit support without examples – 3.
   - List solutions without support – 0.
4. **Anticipate Consequences of the Solutions (10)**
   - Describe the consequence of the solutions with detailed evidences and examples – 10.
   - Describe the consequence of the solutions without examples – 6.
   - Infer the consequence of the solutions – 3.
   - Not describe the consequence of the solutions – 0.

The response was reviewed and evaluated using the preliminary scoring rubric. During this process, the scoring rubric was modified with the aim of capturing the characteristics of the data. Next, one report was randomly selected from each group as a sample report for each condition. The researcher and the first domain expert together scored these four sample reports using this scoring rubric. They discussed the rubric during their scoring process. After discussion and revision, the scoring rubric was finalized for this study. One or two examples were identified from the sample reports for each criterion in the rubric (Table 2).

Besides the research investigator, a doctoral student in instructional psychology was invited to review the students' problem solving reports. After a one-hour training on scoring, the reviewers blind-scored each student case independently. Then they 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 recorded for analysis.

DATA ANALYSES AND RESULTS

INTER-RATER RELIABILITY TEST

The inter-rater reliability for the scoring was calculated by using Pearson Bivariate Correlation. 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 ($r = .856$, $p < .001$), representation 2 ($r = .745$, $p < .001$), representation 3 ($r = .738$, $p < .001$), and representation 4 ($r = .821$, $p < .001$). There were significant correlations between the scores of the two reviewers on problem solution 1 ($r = .698$, $p < .001$), solution 2 ($r = .756$, $p < .001$), solution 3 ($r = .781$, $p < .001$), and solution 4 ($r = .811$, $p < .001$). The magnitudes of these correlations were large according to Cohen's (1988) standard. The strong correlations among these variables of interest suggested that the agreement between the two reviewers in their scoring was high and this inter-rater reliability for the scoring rubric indicates the implementation of the rating system was consistent between reviewers.

CORRELATION ANALYSES

A Pearsons' correlation was used to examine the relationship among students' confidence scores (including classroom management confidence, technology confidence, writing confidence) and the problem solving scores. The purpose of this examination was to determine whether covariates needed to be involved in the later multivariate analyses.

The results indicated that classroom management confidence and the number of problem solutions had a significant negative correlation ($r = -.292$, $p < .05$) 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. Therefore, none were used as covariates in the following MANOVA tests.

A Pearson's correlation also was used to examine the relationship among the scores of problem solving components. The results of this analysis provide statistical justifications for using Multivariate Analysis of Variance (MANOVA) (Stevens, 2002). The correlation matrix (Table 3) shows a moderately strong correlation pattern among the variables. The four problem representation variables all were significantly correlated with each other. The four problem solution variables were significantly correlated with each other. With regard to the correlations between problem representation variables and problem solution variables, there also were significances, such as the number of problems represented and the number of solutions (r = .452, p < .01), problem description and quality of solutions (r = .435, p < .01), problem description and the rationale for solutions (r = .261, p < .05), goal definition for representation and quality of solution (r = .404, p < .01), rationale for representation and quality of solutions (r = .529, p < .01), rationale for representation and rationale for solutions were also significantly correlated (r = .417, p < .01). This correlation pattern indicates the problem solving variables were interrelated with each other and together reflect different aspects of student problem solving abilities.

Table 3. 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).
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. *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.*

MANOVA AND ANOVA

To discover the differences in student problem solving among groups in different treatment conditions, a 2 x 2 MANOVA was calculated. The dependent variables 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 included question prompts and online collaboration. All the analyses were tested at a significance level of .05.

The results of the MANOVA revealed a significant main effect of question prompts on problem solving variables (Wilks' Lambda = 7.25, $F_{(8, 49)}$ = 2.323, p < .05) with moderate effect size ($\eta^2 = .275$)(Cohen, 1988). However, there was not a significant main effect for online peer collaboration and no significant interaction occurred at the multivariate level.

Follow-up ANOVAs revealed that the effects of question prompts were significant on the problem representation variables, including (a) the number of problems ($F_{(1, 56)} = 5.427$, $p < .05$; $\eta^2 = .088$), (b) defining the goal of the problems ($F_{(1, 56)} = 4.399$, $p < .05$; $\eta^2 = .073$), and (c) providing justification for problem representation ($F_{(1, 56)} = 5.323$, $p < .05$; $\eta^2 = .087$). Means indicated students who received question prompts performed better on these problem-representation variables than did those who worked without prompts. Follow-up ANOVAs revealed that the effects of question prompts also were significant on the problem solution variables, including (a) the number of solutions ($F_{(1, 56)} = 12.007$, $p < .01$; $\eta^2 = .177$), (b) the quality of solutions ($F_{(1, 56)} = 7.473$, $p < .01$; $\eta^2 = .118$), and (c) providing rationales for solutions ($F_{(1, 56)} = 6.723$, $p < .05$; $\eta^2 = .107$). Means indicated students who received question prompts performed better on these problem-solution variables than did those who worked without prompts.

However, the main effects of question prompts for (a) the description of the problems, of which means 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), and (b) the solution consequence anticipation, of which means 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), were not significant at the univariate level. There were no significant main effects of online peer collaboration or significant interaction at the univariate level.

DISCUSSIONS

EFFECTS OF QUESTION PROMPTS

The results of this study suggest that students who received question prompts performed significantly better in solving ill-structured problems than did students working without question prompts. Specifically, 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.

These results suggested that the 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 question 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 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 question prompts guided students to go through each component in the process of solving ill-structured problems. Students who received question prompts defined the goal of the problems more clearly and categorized the problems into the correct categories with detailed explanation. They also 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 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.

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. 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 even skipped by novice problem solvers (Salomon, 1987). Making these implicit processes explicit by way of question prompts helped problem solvers internalize problem solving knowledge and transfer it to different problem situations.

However, it was 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 indicated that students performed fairly well on describing the symptoms of the problems across all the treatment groups. 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 consequences suggested that students did relatively poorly in this process across all the treatment groups. Anticipating consequences 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 results might be due to the developmental level of the task was too advanced for students' potential ability. The question prompts designed in this study was not sufficient for supporting anticipating solution consequences. More specific guidance or more detailed prompts might help students perform better on the solution evaluation component in problem solving.

EFFECTS OF ONLINE PEER COLLABORATION

The expected significant effects of 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).

These results were consistent with Ge and Land's that face-to-face peer collaboration did not significantly impact problem solving process at either the overall level or univariate levels. They pointed out that time constrains and the short treatment period could be a possible reason for their non-significant findings (Ge & Land, 2003). 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). 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). 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 be developed.

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 experimental environment. Although at the beginning of this study the animation clips introduced the functions and tools 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. In addition, the collaboration reminders only reminded students to discuss the case with their partners. These reminders did not provide detailed strategies to support students' discussion. 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. Comparing to in authentic problem solving situations, students in this study might not have seen the value and the need for the online peer collaboration. From the field observations, many students tended to rush through the research procedures. Some of their "collaborations" were more like fulfilling 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.

EFFECTS OF INTERACTION

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. 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. 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 any other process of solving ill-structured problems.

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 also need specific guidance on how to collaborate in order to make effective collaboration (Zhang & Peck, 2003). Therefore, more specific collaboration prompts need to be designed to support the collaboration process. This type of question prompt may direct student peers to develop critical thinking and promote argumentation during the collaborative problem solving process. Second, compared with human moderation, pre-designed 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 have two-way interaction 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 collaboration question prompts, 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.

IMPLICATIONS

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

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. Therefore, when instructional designers are planning problem solving activities in their instruction, especially web-based instructions, they need to consider using question prompts as a scaffolding strategy. Due to lack of face-to-face communication between students and teacher in web-based learning environment, specific supports are needed in the problem solving activities. 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 poorly 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, and the collaboration requirement should represent an authentic need. 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 technology training for students so that they can be 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 these environments. 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.

FUTURE RESEARCH DIRECTIONS

The present study also provides some suggestions for future research in this area. First, 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, 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.

Third, 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. 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.

REFERENCES

Benfield, G. (2002). Designing and managing effective online discussions: Oxford Centre for Staff and Learning Development OCSLD.

Bernard, R. M., Rojo de Rubalcava, B., & St-Pierre, D. (2000). Collaborative online distance learning: Issue for future practice and research. *Distance Education, 21*(7), 260-277.

Cheung, W. S., & Hew, K. F. (2004). Evaluating the extent of ill-structured problem-solving process among pre-service teachers in an asynchronous online discussion and reflection log learning environment. *Journal of Educational Computing Research, 30*(3), 197-227.

Choi, I., Land, S. M., & Turgeon, A. J. (2005). Scaffolding peer-questioning strategies to facilitate metacognition during online small group discussion. *Instructional Science, 33*(5-6), 483-511.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Davis, E. A. (1996). Metacognitive scaffolding to foster scientific explanations. Paper presented at the Annual Meeting of American Educational Research Association, New York, NY.

Davis, E. A., & Linn, M. C. (2000). Scaffolding students' knowledge integration: prompts for reflection in KIE. *International Journal of Science Education, 22*(8), 819-837.

Dillenbourg, P., Mendelsohn, P., & Schneider, D. (1994). The distribution of pedagogical roles in a multi-agent learning environment. In R. Lewis & P. Mendelsohn (Eds.), *Lessons from Learning* (pp. 199-216). North-Holland.

Fawcett, L. M., & Garton, A. F. (2005). The effect of peer collaboration on children's problem-solving ability. *British Journal of Educational Psychology, 75*(2), 157-169.

Flannery, J. L. (1994). Teachers as co-conspirator: knowledge and authority in collaborative learning. In K. Bosworth & S. J. Hamilton (Eds.), *Collaborative Learning: Underlying Processes and Effective Techniques* (pp. 15-23). San Francisco: Jossey-Bass Publishers.

Ge, X., & Land, S. M. (2003). Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions. *Educational Technology Research and Development, 51*(1), 21-38.

Ge, X., & Land, S. M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development, 52*(2), 5-22.

Gersick, G. J. (1988). Time and transition in work teams: Toward a new model of group development. *Academy of Management Journal, 31*(1), 9-41.

Hacker, D. J., & Tenent, A. (2002). Implementing reciprocal teaching in the classroom: Overcoming obstacles and making modifications. *Journal of Educational Psychology, 94*(4), 699-718.

Hogan, D.M. & Tudge, J.R.H. (1999). Implications of Vygotsky's Theory for Peer Learning. In A. M. O'Donnell & A. King (Eds.), *Cognitive Perspectives on Peer Learning* (pp. 39-65). Mahwah, NJ: Lawrence Erlbaum.

Horton, W. (2000). *Designing Web-Based Training*. New York: John Wiley & Sons, Inc.

Johnson, D. W., Johnson, R. T., & Smith, C. A. (1991). *Cooperative learning: Increasing college faculty instructional productivity*. Washington, D.C.: School of Education and Human Development, The George Washington University.

Johnson, E. J. (1988). Expertise and decision under uncertainty: Performance and process. In M. T. H. Chi, R. Glaser & M. J. Farr (Eds.), *The Nature of Expertise* (pp. 209-228). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Kauffman, D., Ge, X., Chen, C.H., & Xie, K. (April, 2005). Prompting in web-based environments: Scaffolding self-monitoring skills in college age students. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Katz, S., Aronis, J., & Creitz, C. (2000). Modeling pedagogical interactions with machine learning. *Kognitionswissenschaft, 9*(1), 45-49.

Katz, S., & Lesgold, A. (1993). The role of the tutor in computer-based collaborative learning situations. In S. P. Lajoie & S. J. Derry (Eds.), *Computer as Cognitive Tools* (pp. 289-317). Hillsdale, NJ: Lawrence Erlbaum.

King, A. (1991a). Effects of training in strategic questioning on children's problem-solving performance. *Journal of Educational Psychology, 83*(3), 307-317.

King, A. (1991b). Improving lecture comprehension: Effects of a metacognitive strategy. *Applied Cognitive Psychology, 5*(4), 331-346.

King, A. (1992). Facilitating elaborative learning through guided student-generated questioning. *Educational Psychologist, 27*(1), 111-126.

King, A. (1994). Guiding knowledge construction in the classroom: effects of teaching children how to question and how to explain. *American Educational Research Journal, 31*(2), 338-368.

Kozma, R. (2000). Reflections on the state of educational technology research and development. *Educational Technology Research and Development, 48*(1), 5-15.

Lin, G. L. (1993). *Three's company: A social learning system.* National Central University, Taiwan.

Lin, X. (2001). Designing metacognitive activities. *Educational Technology Research and Development, 49*(2), 23-40.

Lin, X., & Lehman, J. D. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. *Journal of Research and Science Teaching, 36*(7), 837-858.

Mergendoller, J. R., Bellisimo, Y., & Maxwell, N. L. (2000). Comparing problem-based learning and traditional instruction in high school economics. *Journal of Educational Research, 93*(6), 374-383.

Rosenshine, B., & Meister, C. (1992). The use of scaffolds for teaching higher-level cognitive strategies. *Educational Leadership, 49*(7), 26-33.

Rosenshine, B., & Meister, C. (1994). Reciprocal teaching: A review of the research. *Review of Educational Research, 64*(4), 479-530.

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research, 66*(2), 181-221.

Salomon, G. (1987). The computer as a zone of proximal development: internalizing reading-related metacognitions from a reading partner. *Journal of Educational Psychology, 81*(4), 620-627.

Scardamalia, M., & Bereiter, C. (1985). Fostering the development of self-regulation in children's knowledge processing. In S. F. Chipman, J. W. Segal & R. Glaser (Eds.), *Thinking and Learning Skills: Research and Open Questions* (Vol. 2, pp. 563-577). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Scardamalia, M., Bereiter, C., & Lamon, M. (1994). The CSILE project: Trying to bring the classroom into world 3. In K. McGilly (Ed.), *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice* (pp. 201-228). Cambridge, MA: Bradford Books/MIT press.

Scardamalia, M., Bereiter, C., McLean, R. S., Swallow, J., & Woodruff, E. (1989). Computer-supported intentional learning environments. *Journal of Educational Computing Research, 5*(1), 51-68.

Schoenfeld, A. H. (1985). Mathematical problem-solving New York: Academic Press.

Stevens, J. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Tuckman, B.W. (1965). Developmental sequence in small groups. *Psychological Bulletin, 63*(6), 384-399.

Uribe, D., Klein, J. D., & Sullivan, H. (2003). The effect of computer-mediated collaborative learning on solving ill-defined problems. *Educational Technology Research & Development, 51*(1), 5-19.

van Drie, J., van Boxtel, C., Jaspers, J., & Kanselaar, G. (2005). Effects of representational guidance on domain specific reasoning in CSCL. *Computers in Human Behavior, 21*(4), 575-602.

Vygotsky, L. S. (1978). *Mind in Society: the development of higher psychological processes.* Cambridge, Massachusetts: Harvard University Press.

Webb, N. M., & Farivar, S. (1999). Developing productive group interaction in middle school mathematics. In A. M. O'Donnell & A. King (Eds.), *Cognitive Perspectives on Peer Learning* (pp. 117-149). Mahwah, NJ: Lawrence Erlbaum.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem-solving. *Journal of Child Psychology and Psychiatry, 17*(2), 89-100.

Xie, K., DeBacker, T. K., & Ferguson, C. (2006). Extending the traditional classroom through online discussion: The role of student motivation. *Journal of Educational Computing Research, 34*(1), 67-89.

Zellermayer, M., Salomon, G., Globerson, T., & Givon, H. (1991). Enhancing writing-related metacognitions through a computerized writing partner. *American Educational Research Journal, 28*(2), 373-391.

Zhang, K. (2004). Effects of peer-controlled or externally structured and moderated online collaboration on group problem-solving processes and related individual attitudes in well-structured and ill-structured small group solving in a hybrid course. Published dissertation, Pennsylvania State University, University Park, PA.

Zhang, K., & Ge, X. (2005). Dynamic contexts of online collaborative learning. In A. D. de Figueiredo & A. P. Afonso (Eds.), *Managing Learning in Virtual Settings: The Role of the Context* (pp. 97-115). Calgary, AB. Canada: Idea Group, Inc.

Zhang, K., & Peck, K. L. (2003). The effects of peer-controlled or moderated online collaboration on group problem-solving and related attitudes. *Canadian Journal of Learning and Technology, 29*(3), 93-112.