The Effect of Computer-Mediated Collaborative Learning on Solving Ill-Defined Problems

□ Daniel Uribe
James D. Klein
Howard Sullivan

The positive effects of collaborative learning in a face-to-face environment are well known. However, little empirical research exists to determine if such effects transfer to a computer-mediated environment. The purpose of this study was to investigate the effect of computer-mediated collaboration on solving ill-defined problems. Participants first worked through a Web-based instructional program that taught them a four-step problem-solving process. Then they worked in computer-mediated dyads or alone to apply the steps to solve a realistic problem scenario. Results indicated that participants who worked in computer-mediated collaborative dyads performed significantly better than did participants who worked alone. The results also indicated that dyads spent significantly more time than participants in the individual treatment. Both treatment groups had positive attitudes toward working collaboratively, Internet-based instruction, and transfer of problem-solving skills. Implications for the implementation of computer-mediated collaboration in distance learning are discussed.

□ Problem solving is regarded as one of the most important cognitive activities in everyday life and a primary goal of the education process (Jonassen, 2000; Phye, 2001). A possible approach for students to gain this critical skill is through problem-based learning. Proponents of problem-based learning describe it as a powerful instructional approach that is engaging and that leads to sustained and transferable learning of problem-solving skills (Mergendoller, Bellisimo, & Maxwell, 2000; Stepien & Gallagher, 1993).

Problem-based learning uses authentic, complex problems as the impetus for learning and fosters the acquisition of both disciplinary knowledge and problem-solving skills (Edens, 2000; Flynn & Klein, 2001; Levin, 1995). Because of its potential to enhance knowledge acquisition, problem-based learning has become a popular method to deliver classroom instruction in education, and has been widely implemented in a variety of other academic environments (Edens; Flynn & Klein; Kinzie, Hrabe, & Larsen, 1998, Shulman, 1992).

Current research suggests that a collaborative learning environment can positively affect performance on problem-solving tasks. *Collaborative learning* is defined as "an activity that is undertaken by equal partners who work jointly on the same problem rather than on different components of the problem" (Brandon & Hollingshead, 1999). A meta-analysis of the use of collaborative learning in higher education courses indicated that collaborative learning promotes higher achievement, higher level reasoning, more

ETR&D, Vol. 51, No. 1, 2003, pp. 5–19 ISSN 1042-1629

frequent generation of ideas and solutions, and greater transfer of learning than individual or competitive learning strategies (Johnson, Johnson, & Smith, 1991). In another meta-analysis of 122 studies that examined small group and individual learning with technology, small groups were found to be a more effective learning structure than individual learning (Lou, Abrami, & d'Apollonia, 2001).

The research conducted to examine the effect of collaboration on problem solving supports the hypothesis that a collaborative learning environment is well suited for problem-solving tasks. In several case studies conducted to analyze the impact of a collaborative environment on problem solving, collaboration was found to improve performance on complex or higher order thinking activities (Chang & Smith, 1991; Johnson & Chung, 1999; Mergendoller et al., 2000). In these studies, learners appeared to benefit from the ability to discuss the problem, brainstorm potential solutions, and arrive at a final solution. However, these studies have been conducted in face-to-face environments; there is little empirical evidence to indicate if the positive effects of collaborative learning during problem-solving tasks will transfer to a computer-mediated collaborative environment. With enrollments in courses delivered over the Internet in the United States already in the six figures (Simonson, Smaldino, Albright, & Zvacek, 2000), it is important to investigate if the positive effects of a collaborative learning in a face-to-face environment transfer to a computer-mediated collaborative learning structure.

The characteristics of the Internet and a computer-mediated environment appear to make them ideal for problem-based learning. According to Laffey, Tupper, Musser, and Wedman (1998), computer-mediated learning on the Internet is suitable for project-based learning because it provides ample resources, allowing students to do their own planning and present new forms of knowledge, which expands the mechanisms for collaboration and communication. Others also argue that computer-mediated collaboration and the Web are excellent technologies for case studies and integrating higher order learning (Jonassen, Prevish, Christy, & Stavrulaki, 1999).

Empirical research on the effects of synchronous computer-mediated learning on problem-solving skills is sparse. According to Murphy and Collins (1997), research on synchronous computer-mediated communication has been limited to investigations of the recreational use of online chat systems, but the use of these systems for instructional purposes, and specifically for problem-solving tasks, has been explored only through case studies. These case studies support the hypothesis that the benefits of collaborative environment in a face-to-face environment transfer to a computer-mediated environment.

Current research on computer-mediated collaborative learning indicates that it is effective when students are faced with higher order cognitive tasks such as problem solving (Johnston, 1996). In a short pilot study on the use of computer-mediated collaborative groups in postcompulsory teacher education in the United Kingdom, results indicated that students using computer-mediated communications worked better with higher order cognitive tasks than students in the control group (Hall, 1997). In another case study where collaborative learning facilitated through computer-communication was used, nurse practitioners appeared to derive more benefit from the experience of their peers by working and sharing information via computer-mediated communications (Naidu & Oliver, 1999).

Current research also indicates that the quality of interaction between learners in a computer-mediated environment may actually be better than interaction in a face-to-face environment. Findings in a case study suggested that computer-mediated groups seemed to put more thought into the comments they made, thus providing higher quality responses (Camin, Glicken, Hall, Quarantillo, & Merenstein, 2001). In another study findings indicated that the interaction patterns of computer-mediated groups resembled thoughtful discussions whereas face-to-face interactions resembled recitations (Hillman, 1999). And in yet another study where computer-mediated communications were compared to face-to-face interactions, findings suggested that in the computer-mediated environment there was a tendency to share ideas without the restraints of typical social conventions, resulting in deeper and more thoughtful discussions (Kruger & Cohen, 1996).

Another variable that has been shown to influence achievement in a collaborative setting is ability grouping. Ability grouping is the assignment of participants to small groups based on general academic ability. Although studies addressing ability grouping when solving ill-defined problems in computer-mediated environment are rare, several studies have addressed ability grouping in face-to-face collaborative or cooperative environments. Some of these studies suggest that heterogeneous grouping should be used in collaborative environments since this allows for the higher ability student to help and encourage the lower ability student (Johnson, Johnson, & Holubec, 1990; Slavin, 1993).

In a meta-analysis of 27 studies dealing with ability grouping conducted by Slavin (1993), there was little to no achievement difference reported between students grouped heterogeneously versus homogeneously by ability. However, the lower ability students indicated more favorable attitudes toward learning when grouped with students of higher ability (as cited in Sherman & Klein, 1995). But other studies suggest that homogeneous grouping may be the best alternative when working cooperatively. In a study by Sherman and Klein (1995), findings showed that the self-confidence of high-ability students was negatively affected by being paired with a low-ability student. This is in line with other research, which has shown a negative impact on high-ability students when paired in heterogeneous dyads. (Hooper, 1992; Hooper & Hannafin, 1991).

The current study investigated the effects of two levels of learning structure (individual Web-based learning versus computer-mediated collaborative Web-based learning) and ability grouping (high vs. low) on learner performance in solving ill-defined problems. Data on performance, attitudes, and time on task were collected for all participants. Data were also collected on the quality of interactions between participants in the computer-mediated collaborative learning group. The research questions for this study were:

1. Does learning structure (individual Web-based learning versus computer-mediated collaborative Web-based learning) affect learner performance in solving ill-defined problems in a Web-based program?
2. Does ability grouping (high vs. low) affect learner performance in solving ill-defined problems?
3. Does collaboration reduce variability in test scores among learners?
4. Do learning structure and ability grouping affect time on task?
5. Does learning structure affect learner attitudes toward collaborative learning, Web-based instructional programs, and transfer of problem-solving skills to other tasks?

Based on the review of the literature, four outcomes were predicted for this study. First, that participants working in computer-mediated collaborative groups would perform significantly better in resolving ill-defined problems than participants who worked individually (Johnson et al., 1991; Lou et al., 2001); second, that higher ability participants would outperform lower ability participants (Sherman & Klein, 1995); third, that since participants working in dyads would spend time in discussion, it would take them longer to complete the program than participants working alone (Johnson et al., 1991; Lou et at., 2001); and finally, that participants in both treatment groups would have a positive attitude toward collaborative learning, Web-based instruction, and transfer of problem-solving skills (Johnson et al., 1991; Lou et at., 2001; Sherman & Klein, 1995).

METHOD

Participants

The participants in this experiment were 59 Reserve Officer Training Corps (ROTC) students from a large southwestern university in the United States. All participants were enrolled in an aerospace studies course required of all ROTC students. All participants were volunteers and were selected based on whether or not they had been previously trained on the problem-solving process that was used in this study. Only cadets that had not been previously trained were selected. There were 47 male and 12 female participants.

Materials

The materials for this study were developed and incorporated into a Web-based interface through the Blackboard™ course management system. Blackboard is a course management system that provides faculty members the ability to deliver courses over the World Wide Web. The study consisted of four items embedded within the Blackboard interface: (a) an instructional program, (b) a knowledge quiz, (c) a problem scenario, and (d) the assessment questions for the problem scenario.

Instructional program. A Web-based instructional program on problem solving was developed for this study using Authorware™. The instructional program focused on a four-step problem-solving process derived from the Air Force "Six-Step Problem-Solving Process" commonly taught to college juniors enrolled in the Air Force ROTC program. The six-step process was streamlined to four steps for ease of delivery in a Web-based environment. The two major differences between the six-step and the four-step processes were that in the four-step version, (a) two steps were combined into one (developing and testing possible solutions), and (b) a final step to implement and monitor the solution was deleted. The modified approach was intended to provide students with a tool to solve complex problems in a Web-based environment.

The instructional program is Web-based and interactive. An animated cartoon (the "agent") leads the students through the following four steps: (a) defining the problem, (b) gathering data, (c) developing and testing possible solutions, and (d) selecting the best possible solution. The agent explanations were all text-based; no audio was included in this version of the instructional program. The agent explains each step and then uses a problem scenario to show the learners how to apply the step. For example, as part of the instruction for Step 1 (defining the problem), the agent explains that the learner must identify the individuals involved, the goal, and the obstacle preventing achievement of the goal. The agent then uses a problem scenario to highlight each of the elements of the problem environment and how these lead to a problem statement. The learner then practices describing the problem environment and writing a problem statement with a different problem scenario. Overall, the student is exposed to two different problem scenarios throughout the program. The first scenario is solved by the agent as he explains each step of the process. The second problem scenario is solved by the student as he or she practices each step. After completing the instructional program, the participants are administered a knowledge quiz on the four-step problem-solving process.

Knowledge quiz. A 10-item multiple-choice quiz was developed to assess how well students learned the four-step process. The questions addressed things such as the sequence of the steps, subtasks within each step, and critical outcomes of each step. The following is an example of the type of multiple-choice question found in the knowledge quiz. The students were able to choose only one answer:

Which of the following statements would you classify as criteria?

(a) Survey results indicate the personnel like the new dorms.

(b) ASAP means As Soon As Possible.

(c) The chief of logistics thinks the job should only take a day.

(d) Your boss says you have three days to find a solution.

The quiz scores indicated that the participants learned the problem-solving process well ($M = 8.98$, $SD = 1.06$). The quiz results were positive across both treatment groups and ability levels. The average score for higher ability participants working in dyads was 9.37, $SD = .62$, while the average score for lower ability participants working in dyads was 9.1, $SD = 1.1$. Higher ability participants working individually scored an average of 9.1, $SD = .99$, while lower ability participants working individually scored an average of 8.4, $SD = 1.3$. After completing the quiz the participants were instructed to apply the process they had just learned to a realistic problem scenario.

Assessment problem scenario. The assessment scenario was developed with a military theme and portrayed a realistic personnel issue that the officer candidates participating in the study might face in the future. The following is the entire problem scenario text.

1000 Hours: somewhere in the jungles of a small Caribbean island . . .

You are Capt. Klein, assigned to Joint Task Force-Bravo, participating in a multinational peacekeeping operation in the island of Tamos (fictitious). Troops from Peru, Honduras, Guatemala, Ecuador and the United States were deployed to restore and keep the peace in this small Caribbean nation. You are in command of an Air Force logistics squadron with 10 members composed of 2 members from all participating nations. As you focus on accomplishing the mission, you receive a request from a member of the Ecuadorian Air Force for a transfer out of the unit. You know your boss Col. Sullivan will not allow any personnel transfers. You know you'll need to brief the problem and your recommended solution at the next staff meeting. . . .

As part of the problem scenario, the participants had access to additional information in the form of simulated interviews with the individuals involved in the problem scenario and Web sites that provided information the student could use to solve the problem. Once the participants felt they were ready, they navigated to the assessment area of Blackboard where they answered four essay questions that paralleled the steps of the four-step problem-solving process. All of the participants, including those working in dyads, submitted individual answers for each question. The Blackboard system was set up to allow the participants to change an answer after it had been submitted. The four essay questions the students had to answer as part of the problem scenario were:

1. Define the overall problem environment and write a problem statement.
2. List and categorize the data that are relevant for solving this problem.
3. List as many solutions as possible that meet your criteria.
4. List additional criteria and select the best possible solution for this problem scenario.

Scoring rubric. The lead researcher developed the scoring rubric used to evaluate the participants' responses to the essay questions. Given the nature of an ill-defined problem scenario where multiple solutions are possible, there was not a single right or wrong answer. Instead, points were awarded for how well the students applied each step of the process. The four essay questions paralleled the four steps of the problem-solving process. Under Step 1, Defining the Problem, the participants were evaluated on the clarity of the problem statement and how well they identified the elements of the problem environment, which include the individuals involved, the goal, and the obstacle. Under Step 2, Gathering Data, the participants were evaluated on the amount and quality of data gathered and on the data classification. Under Step 3, Developing and Testing Possible Solutions, the participants were assessed on the number and quality of solutions. Finally, under Step 4, Selecting the Best Possible Answer, the participants were assessed on the additional criteria used and on the recommended solution.

The scoring rubric was designed to assess participant performance on each step by breaking down the step into subcategories and using a rating scale to assign a score based on three different levels of performance. The participants received 0, 1, or 2 points for each subcategory, depending on the quality of the answer. For example, for identifying the goal under Step 1, the participant received no points if no goal was identified, 1 point if a goal was identified but was unclear or inconsistent with the problem scenario, and 2 points if the goal was clearly stated (i.e., "The goal is unity within the squadron"). As another example, when selecting the best possible solution under Step 4, the participants received no points if no solutions were provided, 1 point if a solution was provided but it was not a logical choice given the data gathered in the previous steps, and 2 points if the solution was a logical choice given the data and criteria gathered in previous steps.

The overall points assigned to each step were based on the amount of information that was expected from each participant. Step 1 had four subcategories and was worth 8 points because the instructional program placed a heavy emphasis on identifying the problem, while Steps 2–4 were worth 4 points each and were divided into two subcategories. The participant responses were blind graded by one of two evaluators to prevent bias in the grading procedure. Interrater reliability was determined by having trained evaluators score four participant responses to the assessment scenario. The evaluators' scores were then processed using Statistical Package for the Social Sciences (SPSS) to compute an interrater reliability of .86.

Attitude Survey. A 10-item survey was developed to measure participant attitudes toward working alone or with a partner, as well as their attitude toward the instructional program and toward transfer to other tasks of the problem-solving skills learned. Respondents used a 5-point Likert scale (1 = *strongly disagree,* 5 = *strongly agree*) to rate their attitude toward working in a Web environment and working alone or in dyads, and their perception of transfer of their problem-solving skills to other real-life-type problems. Additionally, the students were asked to identify their preference for working on complex problems by circling one of two choices: alone or with a partner. Finally, 2 open-ended questions asked the participants what they liked best and least about the program. The alpha reliability coefficient of the survey was .71.

Procedures

The two treatment groups for this study were (a) an individual Web-based learning group and (b) a computer-mediated collaborative Web-based learning group. The individual Web-based learning group initially consisted of an equal number of higher ability and lower ability participants, while the computer-mediated collaborative Web-based learning group consisted of dyads composed of one higher ability and one lower ability student. Students in the individual Web-based learning group worked alone through the entire program. Students in the computer-mediated collaborative Web-based learning group worked individually through the instructional part of the program and then used synchronous computer-mediated communication to work collaboratively on the problem scenario.

The participants were blocked into higher ability and lower ability groups based on their academic composite. The academic composite was calculated using the student's grade point average (GPA) and current average in the ROTC class. In computing the academic composite, the GPA was weighted heavier than current class average because GPA was considered a more reliable indicator of the student's general academic ability. The median split for GPA was 3.4 out of 4.0. Students were then randomly assigned in equal numbers to the individual treatment or computer-mediated collaborative treatment. Within the computer-mediated collaborative group, one higher ability student and one lower ability student were randomly assigned to form dyads. For participants working in dyads, the higher ability participants had a GPA of 3.7, SD = .26, while lower ability participants had a GPA of 2.9, SD = .63. For participants who worked individually, higher ability students had a GPA of 3.7, SD = .20, while lower ability participants had a GPA of 2.9, SD = .44.

Four weeks prior to the study, the participants were instructed to ensure they had a user name and password that allowed them access to the university Blackboard system. If students did not have access to the system, they were provided with instructions on how to get a temporary user name and password in order to participate in the study. One week before the study, participants were given a short briefing on how the study was organized, and its location and time. The participants were also notified that, as an incentive to perform well, the top performers in each treatment group (i.e., top individual student and the two students in the top dyad) would receive a gift certificate to a popular dining establishment. Any technical issues related to access to the Blackboard system were also cleared up during this briefing.

The day of the study, participants were directed to prearranged locations in the computer laboratory that ensured each member of a dyad was physically separated from his or her partner. This was done to prevent verbal or bodily communications between the members of the dyad, thus simulating a distance education environment. The participants were instructed to log in to the Blackboard system and to navigate to the study Web page. Once everyone was properly logged in to Blackboard, the researcher instructed them to follow the instructions on the screen and that they had 1.5 hr to complete the program. The participants were also provided with a hard copy of the instructions.

All students worked through the instructional program individually. Once the participants completed the instructional program, they were instructed to take the knowledge quiz. Once the quiz was completed, participants in the individual group proceeded to the assessment problem scenario while the computer-mediated dyads were instructed by the program to establish communication with their partners and to collaborate on the assessment problem scenario. The communication between members of the dyads took place using the virtual classroom feature of the Blackboard system. This feature allowed the students to chat with their partners by entering a virtual classroom that had been set up by the researchers for each dyad. Each dyad was assigned a different virtual classroom to prevent cross flow of information between dyads. There were no interactions between the participants and the researchers or instructors except to remedy any technical difficulties.

The interactions between the members of each dyad were captured using an automatic function of the virtual classroom within Blackboard that recorded the text communications between members of the dyads. The logs for each dyad were then transferred to a database program and separated by individual entry in order to be analyzed.

Design and Data Analysis

This study was a posttest only 2 (Individual vs. Computer-Mediated Collaborative Learning) × 2 (Higher Ability vs. Lower Ability) factorial design. The primary dependent variable was student performance resolving an ill-defined problem scenario. Time on task and learner attitudes were also analyzed. En route data included a computer record of the interactions between the members of the dyads. The knowledge quiz results were too skewed to be interpretable, therefore only descriptive statistics were used to analyze those data. Analysis of variance (ANOVA) was conducted on participants' performance on the assessment problem scenario and on time on task. Multivariate analysis of variance (MANOVA) was conducted on the data from the attitude survey. One-sample chi-square tests were conducted on the open-ended question: "When solving problems I prefer to work: by myself or with a partner." One chi-square test was conducted to determine the overall student preference, and then a chi-square was performed for treatment group and for ability level.

The interactions between members of the dyads were analyzed using both qualitative and quantitative analysis techniques. The entries in the communications transcripts captured via Blackboard were first grouped into categories based on the type of interaction. The entries were classified as questions, answers, discussions and off-task interactions as determined by the lead researcher, and descriptive statistics were then computed for each category. Previous researchers have used these categories in studies examining small group interactions (Doran & Klein, 1999; Klein & Pridemore, 1994). An entry was classified as a *question* if one member of a dyad requested information or asked for clarification from the other team member (e.g., "Have you looked into the information sites on the Web yet?"). An entry was classified as an *answer* if the communication was in direct response to a question (e.g., "No I haven't. I read the information of some of the members of the squadron"). An entry was considered a *discussion* if the communication directly related to the problem the dyad was trying to solve (e.g., "I think we should find out if sgt robles [sic] knows those comments were offensive . . . solve the problem at the lowest level possible"). Finally, an entry was categorized as an *off-task* discussion if the communication was not related to the problem-solving task (e.g., "dang . . . my keyboard froze . . . but I'm back now!").

RESULTS

Performance by Learning Structure and Ability Level

The first two research questions investigated the effect of learning structure and ability level on performance in solving ill-defined problems. Table 1 shows the mean scores and standard deviations for performance on the assessment scenario. The table reveals that participants who worked in a dyad had an overall average of 11.94 (60%), while participants who worked individually had an average of 9.89 (50%). The data also show that higher ability participants had an overall average of 11.76 (59%) and lower ability participants had an overall average of 10.27 (51%). A 2 × 2 ANOVA conducted on these data revealed that participants working in dyads had a significantly higher performance score than those working alone, $F(1,55) = 6.58$, $p = .01$, $\eta^2 = .11$. Although there was a difference between ability groups, this difference only approached significance ($p = .06$) and there was no significant interaction.

Table 1 ☐ Means scores and standard deviations for performance on the problem scenario.

Ability Level	*CMC Dyads*	*Individuals*	*Overall*
	Learning Structure		
High Ability			
Mean	12.37	11.00	11.76
(*SD*)	(2.94)	(2.89)	2.95
n	16	13	29
Low Ability			
Mean	11.50	8.86	10.27
(*SD*)	(3.12)	(3.01)	(3.3)
n	16	14	30
Over all			
Mean	11.94	9.89	11.00
(*SD*)	(3.01)	(3.09)	(3.19)
n	32	27	59

Note: The maximum number of points on the problem scenario was 20.

Difference Scores Within Dyads

The third research question directly dealt with the impact of collaboration on performance solving ill-defined problems. A posthoc procedure was conducted to better understand the effect of collaboration on performance. It was theorized that the pairs of participants who worked in dyads ($n = 16$) would have performance scores that were more similar to each other than pairs who worked individually but were formed into dyads of one higher ability and one lower ability participant posthoc ($n = 13$) to make this comparison. The rationale was that the collaborative effort in dyads would influence the performance of the two participants to make it more similar to one another, whereas no such influence could be effected in pairs of participants who worked individually but were constructed posthoc. A difference score for each dyad was obtained by subtracting the lower score from the higher score. The data revealed that the average difference between the two participants who worked in each dyad was 1.5 points, $SD = 1.6$, while the difference between participants who worked individually but were assigned to a posthoc dyad was 4.6 points, $SD = 3.1$. An ANOVA performed on these data showed that the mean difference between the students who worked in a dyad was significantly lower than the difference between those who worked individually but were formed into posthoc dyads, $F(1,27) = 11.97$, $p = .002$, $\eta^2 = .31$.

Time on Task

The next research question pertained to the effect of treatment on time on task. Participants in both treatments were allowed a maximum of 90 min to complete the program. The data revealed that higher ability participants who worked individually spent an average of 77.46 min, $SD = 13.61$, while higher ability participants who worked in dyads spent an average of 88.38 min, $SD = 3.44$. Additionally, lower ability participants who worked individually spent an average of 75.29 min, $SD = 15.43$, while lower ability participants who worked with a partner spent an average of 87.88 min, $SD = 4.33$. A 2 × 2

ANOVA indicated that participants who worked in dyads spent significantly more time on task than participants who worked alone, $F(1,55) = 19.24, p < .001, \eta^2 = .26$. The difference between ability groups was not significant and there was no significant interaction.

Participant Attitudes

The last research question investigated the effect of the treatment on the attitudes of the participants. A 2 × 2 MANOVA conducted on student attitudes indicated that learning structure had a significant effect on student attitudes, $F(10,42) = 2.44, p = .022, \eta^2 = .37$. Follow-up ANOVA revealed two significant items. The first item dealt with participant attitude toward time available to complete the program. Participants who worked alone felt they had more time to complete the program ($M = 4.2, SD = 1.22$) than those who worked in dyads ($M = 3.4, SD = 1.0$), $F(1,53) = 6.5, p = .014, \eta^2 = .11$. The second item showing significant difference concerned ease of use of the Blackboard system. Participants who worked alone thought Blackboard was easier to use ($M = 4.4, SD = .65$) than participants who worked in computer-mediated dyads ($M = 3.3, SD = 1.18$), $F(1,53) = 17.42, p < .001, \eta^2 = .25$. The attitude survey further revealed that participants had a generally positive attitude toward working on an Internet-based program ($M = 3.82, SD = .86$) and toward transfer of problem-solving skills to their professional lives ($M = 3.84, SD = .76$).

The attitude survey also included one option question that asked, "When solving problems I prefer to work: BY MYSELF or WITH A PARTNER." A one-sample chi-square test revealed that of the 54 participants who responded to this question 35 indicated a preference for working with a partner while 19 indicated a preference for working alone, χ^2 $(1, N = 54) = 4.74, p = .03$, *effect size* = +0.09. The results by treatment group revealed that 17 of the 24 participants who worked individually indicated a preference for working with a partner, χ^2 $(1, N = 24) = 4.17, p = .04$, *effect size* = +0.17, while 18 out of 30 participants who worked in dyads selected "working with a partner" as a preference, χ^2 $(1, N = 30) = 1.2, p = .27$, *effect size* = +0.04. When analyzed by ability level, 15 of the 27 higher ability participants indicated a preference to work with a partner, χ^2 $(1, N = 27) = .33, p = .564$, *effect size* = +0.01. Additional tests showed that 20 out of 27 lower ability learners indicated a preference to work with a partner, χ^2 $(1, N = 27) = 6.26, p = .012$, *effect size* = +0.23.

The attitude survey also included two open-ended questions that asked the participants what they liked best and least about the program. The top four responses for what participants liked best included (a) the realism of the problem scenario ($n = 13$), (b) using the Internet to solve problems ($n = 9$), (c) the instructional program ($n = 8$), and (d) learning a new approach to solve problems ($n = 8$). The top four responses for the least liked aspects of the program were (a) the difficulties communicating through Blackboard ($n = 17$), (b) working alone ($n = 7$), (c) having to work with a partner ($n = 7$), and (d) lack of time to complete the scenario ($n = 6$).

Interaction Data

The interactions were first reviewed to determine if these data revealed any strategies for problem solving or any evidence that collaboration was beneficial to solving the problems. These findings are reported in the discussion section and are used to support other findings. There was a total of 1,494 communications between the members of the dyads—20% were questions, 18% were answers, 51% were discussions and 11% were off-task entries.

DISCUSSION

The purpose of this study was to investigate the effects of computer-mediated collaborative learning and ability on learner performance solving ill-defined problems. Results indicated that participants who worked in computer-mediated collaborative dyads performed significantly better than did participants who worked alone. The results also indicated that computer-mediated dyads spent significantly more time than participants in the individual treatment, and both treatment groups had positive attitudes toward working collaboratively, toward the instructional program, and toward transfer of problem-solving skills.

Performance by Learning Structure and Ability Level

The initial research questions dealt with the effect of learning structure and ability level on performance in solving ill-defined problems. The finding that computer-mediated dyads performed significantly better than participants who worked alone supports previous findings that showed computer-mediated collaborative learning had a positive effect on achievement (Alavi, 1994; Hall, 1997; Johnston, 1996; Naidu & Oliver, 1999). This result also indicates that the benefits of face-to-face collaboration on problem-solving tasks transfer to a computer-mediated environment. Participants who worked with a partner appeared to have benefited from the ability to discuss the problem and possible solutions, which is in line with findings from studies on face-to-face collaborative environments for problem solving (Chang & Smith, 1991; Flynn & Klein, 2001; Johnson & Chung, 1999; Johnson et al., 1991; Mergendoller et al., 2000).

The superior performance of computer-mediated dyads relative to participants who worked alone also supports the hypothesis that a computer-mediated collaborative environment is well suited for problem-solving activities and higher order learning (Jonassen et al., 1999). It is possible that participants who worked with a partner were able to access more information related to the problem and could generate better problem solutions than their counterparts who worked alone.

A somewhat unexpected result of this study was the nonsignificant difference finding by ability level. There are two possible reasons for these results. First, lower ability participants in the computer-mediated dyads seemed to have benefited by being paired with a higher ability participant. This finding is in line with other research, which has shown that lower ability learners benefit from being paired with higher ability learners (Johnson et al., 1990; Slavin, 1993). An inspection of the means shows that there was a greater difference in the individual treatment between lower ability and higher ability participants than in the computer-mediated collaborative treatment; however, the difference was not enough to yield a significant treatment by ability level interaction. A second possible reason for the nonsignificant finding by ability is that the GPA method used to assign an ability score to each participant may not have been accurate enough. Although GPA can be a good indicator of general academic ability, it may not be a good predictor of specific problem-solving skills.

Difference Scores Within Dyads

Evidence that collaboration in dyads for solving complex tasks positively affected learner performance came from the results of the posthoc procedure conducted with the performance data. These data showed that the difference between the scores of the two participants in a dyad was significantly smaller than in posthoc dyads composed of participants who worked alone. These results are not surprising if we assume that collaboration is indeed taking place. In a truly collaborative environment it would be expected that the members of a dyad would work through the information and arrive at a solution together and would therefore have a greater number of similar responses than posthoc dyads who worked alone. By discussing the information available, the learners who worked with a partner were exposed to another perspective on the problem, which may have helped them to better shape the mental model of the problem environment. This outcome supports previous findings about the quality of interaction in a computer-mediated environment where learners working in computer-mediated environments exhibited more thoughtful discussions (Camin et al., 2001; Hillman, 1999; Kruger & Cohen, 1996).

A look at the interactions that took place between members of the dyads seems to support this argument. The majority of the dyads appeared to follow a similar pattern to arrive at a solution. The first pattern that emerged was an attempt by the dyads to develop a strategy to solve the problem through a question-and-answer exchange. The following is an interaction example from a dyad that used a "divide and conquer" approach to solve the problem:

Participant X: Hello.

Participant Y: Hello!

Participant X: Have you looked into the information sites on the web yet?

Participant Y: No I haven't. I read the information of some of the members of the squadron.

Participant Y: I began to read a little bit about the conflict between Peru and Ecuador.

Participant X: Can we take notes?

Participant Y: Yes.

Participant X: Let's split up the web sites . . .

Participant Y: Ok.

Participant Y: Which three do you want to read?

Participant X: I'll read the first three articles.

Participant Y: Ok. I'll meet you back in here in a few min.

Participant X: ok.

Once the dyads developed a strategy to solve the problem, the second general pattern appeared to be an attempt to follow each step of the problem-solving process by exchanging information through interactions focused on arriving at a problem solution. The following is an example of this type of exchange:

Participant A: I think the problem can be found with MSgt Robles.

Participant A: This is because he doesn't appreciate TSgt Paredes at all.

Participant B: That would be a good assumption.

Participant B: well the research shows that there is conflict with Ecuador and Peru.

Participant A: So what do you feel the overall problem environment is and how would we write a statement about it.

Participant B: I think the problem is that robles and paredes can't get along.

Participant A: I would agree with this however, is this just a result of a bigger problem between their countries.

Participant B: Yes.

Participant A: Our goal would be to have Robles and Paredes get along.

Participant B: I agree.

The analysis of the interaction data may also help to explain why the collaborative dyads performed better and more similarly to each other than individuals. A breakdown of the 1,494 interactions showed that 90% of the communications between participants were focused on asking or answering questions or discussing information related to the problem. It is reasonable to assume that if the participants were focused on solving the task, then the effects of collaboration would be positive.

Time on task

The results of the time-on-task analysis may also help to explain why computer-mediated collaborative dyads performed better than participants who worked alone. The dyads spent significantly more time on the program than participants who worked individually (88.48 min to 76.33 min). This result supports the finding by a meta-analysis of 122 studies dealing with small group and individual learning with technology where students working individually accomplished tasks faster than those working in groups (Lou et al., 2001). It is possible that the dyads generated more possible solutions because they were able to discuss the problem. These interactions may well have been beneficial in developing a better understanding of the problem and formulating more complete answers. The following example highlights how the members of one dyad generated and discussed possible solutions to the problem:

Participant C: What do you think they should do?

Participant D: I think they should be mediated.

Participant C: What if they don't want a mediator?

Participant D: . . . well, what other solutions are there?

Participant C: . . . ignore the problem or let them fight it out.

Participant D: How about disciplinary action?

Participant C: That sounds good.

The following is an example of an exchange that shows how the dyads spent time helping each other get a better understanding of the problem environment:

Participant P: . . . well, what did you come up with for the definition of the problem?

Participant Q: No idea . . ., but I would be wondering why he wants to transfer in the first place.

Participant P: well . . I thought of . . . "I am leading a unit from which one man wants to transfer. My boss won't allow it," so my problem statement would be: "How can we keep the unit together?" . . . sound good?

Participant Q: do you think that the problem is with the man wanting to transfer, or the man not being allowed to transfer?

Participant P: well, I think the problem is with the man wanting to transfer. The unit needs to get the job done. Does the problem statement sound ok?

Participant Q: wait, I want to read real quick why he wants out . . . you're right, sounds like disunity in the unit.

However, the additional time spent on the task led to a perception by the participants who worked in dyads that there was not enough time to complete the program. Learners who worked alone did not have to spend time communicating with a partner and could concentrate on solving the task, while participants who worked in dyads experienced the time delays encountered when having to work with another individual in a computer-mediated environment.

Participant Attitudes

In general, participants indicated a preference for working collaboratively. This supports previous research that has shown a preference by learners to work in a collaborative environment (Johnson et al., 1991; Lou et al., 2001). However, the attitude data suggest that some challenges exist in a computer-mediated collaborative environment. The responses to the open-ended questions suggested that some of the extra time the dyads spent on the program may have been a result of the problems associated with communicating through a computer-mediated medium. Many participants who worked with a partner cited the difficulties of communicating through the computer as the thing they liked least about the program. The following are some examples of the thoughts expressed by the participants when asked, "What did you like least about the program?"

Trying to communicate with my partner.

Keeping contact with my partner was difficult through Blackboard . . .

I didn't like working with a partner over the Internet. It made for slow communication.

I didn't really like using Blackboard to talk to my partner. It is more helpful being able to talk with my partner face to face.

It was a little hard to talk to my partner with just typing.

These findings are supported by the significant differences found on the attitude items related to time available to complete the program and to perceptions on the ease of use of the Blackboard system. Participants who worked alone felt they had enough time to complete the task and that Blackboard was easy to use. However, participants who worked in dyads felt they did not have sufficient time and also felt it was difficult to communicate through Blackboard.

The survey results also show that the participants enjoyed the Internet program and felt they learned a lot from it. This finding supports other research where student attitudes toward Web-based instruction have been found to be positive (Adelskold, 1999; McIsaac & Ralston, 1996; Savenye, 2001). The characteristics of the Internet, such as instant access to various sources of information, appeared to make it attractive for the learners. Some of the comments from the students on the open-ended questions seem to support this explanation, as indicated by their responses when asked what they liked best about the program:

Using the Internet to solve problems and do research.

I did enjoy doing the program over the Internet.

I liked using the Internet. I liked having everything that I needed right at my fingertips.

It was nice having the articles on the Internet and not having to thumb through a bunch of books.

The attitude survey also attempted to gauge the learner perceptions on transfer to their professional lives of the problem skills learned. The results indicated that most participants agreed that what they had learned would transfer to their professional lives. It is possible that the participants felt they would use this process in their professional lives because they thought the problem scenario was realistic and could be something they might face in their future as Air Force officers. The majority of participants indicated that the realism of the problem scenario was what they liked best about the entire program.

Implications

This study has implications for the design and delivery of Internet-based courses. The study indicates that computer-mediated collaborative learning is a more effective strategy when teaching problem-solving skills than is individual learning. The findings of this study are applicable to academic subjects where a high level of real-time interactivity and higher order cognitive skills may be required. However, as the study suggests, text-based communications have some drawbacks that should be considered prior to implementing this type of learning structure. Instructional designers and instructors should keep in mind the increased time necessary in a computer-mediated collaborative environment.

The results of this study also inform the theory of transactional distance. The theory predicts that if the structure of a course is kept constant and dialogue is increased, the decrease in the transactional distance should have a positive effect on performance (Moore & Kearsley, 1996). The structure remained constant for both treatment groups in this study, but the amount of dialogue between learners varied depending on treatment group. The promotion of dialogue between learners in the computer-mediated collaborative dyads seemed to improve understanding of the task and information available, leading to a difference in performance in favor of students working in the computer-mediated environment.

Further Research

The results of this study suggest several specific areas that should be addressed by additional research. The size of the computer-mediated collaborative group should be explored to determine an optimal size. It is possible that given the characteristics of the synchronous communication environment where nonverbal clues such as eye contact, body motion, and so forth, are nonexistent, larger groups will have difficulty communicating. With additional team members, the law of diminishing returns begins to take place and the collaborative environment begins to lose its effectiveness. Future research should also focus on the effectiveness of computer-mediated collaboration on how well students learn a process to solve complex problems. Do students learn a process better, as they appear to do in this study, if they are able to discuss with a peer online?

Another area that could benefit from additional exploration is the effect of computer-mediated collaboration on different types of tasks. It would be useful for instructional designers and practitioners to know if there are certain types of tasks that are better suited for computer-mediated collaboration. For example, the ill-defined problems identified by Jonassen (2000), such as decision-making, strategic performance, case analysis, and design problems could be examined. Investigating these types of problems in a computer-mediated environment should help instructional designers identify the types of problems that are particularly well suited for a computer-mediated environment. A factor that may affect the organization of collaborative groups in a distance-learning environment is social relationships. In this study the dyads were randomly assigned, however, the effect of social relationships on attitudes about heterogeneous grouping could be examined to determine if partner self-selection has an impact on learner attitudes. As the number of distance education courses delivered over the Internet continues to grow, research on the different aspects of computer-mediated collaboration should help us identify effective instructional practices for promoting learning and problem solving. □

Maj. Daniel Uribe [daniel.uribe@usafa.af.mil] is Director of Operations of the Department of Foreign Languages at the United States Air Force Academy, Colorado. During article preparation, he was a PhD student at Arizona State University (ASU), Tempe.

James D. Klein and Howard Sullivan are Professors of Educational Technology at ASU.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

REFERENCES

Adelskold, G. (1999c7). Problem-based distance learning of energy issues via computer network. *Distance Education 20*(1): 129–143.

Alavi, M. (1994). Computer-mediated collaborative learning: An empirical evaluation. *MIS Quarterly*, June, 159–174.

Brandon,D & Hollingshead, A.B. (1999). Collaborative learning and computer-supported groups. *Communication-Education, 48*(2), 109–126.

Camin, C., Glicken, A., Hall, M., Quarantillo, B., & Merenstein, G. (2001). Evaluation of electronic discussion groups as a teaching/learning strategy in an evidence-based medicine course: A pilot study. *Education for Health: Change in Learning and Practice, 14*(1), p.21.

Chang, K.Y.R & Smith, F. (1991). Cooperative learning and CALL/IVD in beginning Spanish: An experiment. *Modern Language Journal, 75*(2), 205–211.

Doran, M.S., & Klein, J.D. (1999). Implementing individual and small group learning structures with a computer simulation. *Educational Technology Research and Development, 47*(1), 97–110.

Edens, K.M. (2000). Promoting communication, inquiry, and reflection in an early practicum experience via an on-line discussion group. *Action in Teacher Education, 22*(2A), 14–23.

Flynn, A.E., & Klein, J.D. (2001). The influence of discussion groups in a case-based learning environment. *Educational Technology Research and Development, 49*(3), 71–86.

Hall, D. (1997). Computer mediated communication in post-compulsory teacher education. *Open Learning, 12*(3), 54–56.

Hillman, D. C. A. 1999). A new method for analyzing patterns of interaction. *The American Journal of Distance Education, 13*(2), 37–47.

Hooper, S. (1992). Effects of peer interaction during computer-based mathematics instruction. *Journal of Educational Research, 85*(3), 180–189.

Hooper, S., & Hannafin, M.J. (1991). The effects of group composition on achievement, interaction, and learning efficiency during computer-based cooperative instruction. *Educational Technology, Research and Development*, 39(3), 27–40.

Johnson, D.W., Johnson, R.T., & Holubec, E.J. (1990). *Circles of learning: Cooperation in the classroom.* Edina, MN: Interaction Book Company.

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, S.D., & Chung, S.P. (1999). The effect of thinking aloud pair problem solving (TAPPS) on the troubleshooting ability of aviation technician students. *Journal of Industrial Teacher Education*, 37(1), 7–25.

Johnston, V.L. (1996), Toward a global classroom using computer-mediated communications at UAA. University of Alaska Anchorage, *Vocational Teacher Education Research Report,* (Eric document # ED356759)

Jonassen, D.H. (2000). Toward a design theory of problem solving. *Educational Technology, Research and Development, 48*(4), 63–85.

Jonassen, D., Prevish, T., Christy, D., & Stavrulaki, E. (1999). Learning to solve problems on the Web: Aggregate planning in a business management course. *Distance Education*, 20(1), 49–63.

Kinzie, M.B., Hrabe, M.B., & Larsen, V.A. (1998). An instructional design case event: Exploring issues in professional practice. *Educational Technology Research and Development, 46*(1), 53–71.

Klein, J.D., & Pridemore, D.R. (1994). Effects of orienting activities and practice on achievement, continuing motivation, and student behaviors in a cooperative learning environment. *Educational Technology Research and Development. 42*(4), 41–54.

Kruger, L.J., & Cohen, S. (1996). Using the Internet to extend training in team problem solving. *Behavior Research Methods, Instruments and Computers, 28*(2), 248–253.

Laffey, J., Tupper, T., Musser, D., & Wedman, J. (1998). A computer-mediated support system for project-based learning. *Educational Technology Research and Development, 46*(1): 73–86.

Levin, B.B. (1995). Using the case method in teacher education: The role of discussion and experience in teachers thinking about cases. *Teaching and Teacher Education, 11*(1), 63–79.

Lou, Y., Abrami, P.C., & d'Apollonia, S. (2001). Small group and individual learning with technology: A meta-analysis. *Review of Educational Research, 71*(3), 449–521.

McIsaac, M.S., & Ralston, K.D. (1996). Teaching at a distance using computer conferencing. *Tech Trends*, 41(6), 48–53.

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.

Moore, M.G., & Kearsley, G. (1996). *Distance education: A systems view.* New York: Wadsworth Publishing Company.

Murphy, K.L., & Collins, M.P. (1997). Development of communication conventions in instructional electronic chats. *Journal of Distance Education, 12*(1), 177–200.

Naidu, S., & Oliver, M. (1999). Critical incident-based computer supported collaborative learning. *Instructional Science, 27*(5), 329–354.

Phye, G.D. (2001). Problem-solving instruction and problem-solving transfer: The correspondence issue. *Journal of Educational Psychology, 93*(3), 571–578.

Savenye, W.C. (2001). *Evaluating Web-based learning systems and software.* Paper presented at the Conference on Instructional Design: Addressing the Challenges of Learning Through Technology and Curriculum, Albert-Ludwigs Universitat, Freiburg im Breisgau, Germany, May 2001.

Sherman, G.P., & Klein, J.D. (1995). The effects of cued interaction and ability grouping during cooperative computer-based science instruction. *Educational Technology Research and Development, 43*(4), 5–24.

Shulman, J. (Ed.). (1992), *Case method in teacher education.* New York: Teachers College Press.

Simonson, M., Smaldino, S., Albright, M., & Zvacek, S. (2000). *Teaching and learning at a distance: Foundations of distance education.* Upper Saddle River, N.J.: Merrill an Imprint of Prentice Hall.

Slavin, R. (1993). Ability grouping in the middle grades: Achievement effects and alternatives. *Elementary School Journal, 93*(5), 535–552.

Stepien, W., & Gallagher, S. (1993). Problem-based learning: As authentic as it gets. *Educational Leadership, 50*(7), 25–28.