EFFECTS OF COLLABORATION MODE AND GROUP COMPOSITION IN COMPUTER-MEDIATED INSTRUCTION

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Abstract

This study investigated the effects of collaboration mode and group composition during a collaborative computer-based program. Each of six intact sections of a computer literacy course was assigned to either a face-to-face or a virtual, online collaboration treatment condition. Groups consisted of homogeneous lower-ability, homogeneous higher-ability, or heterogeneous mixed-ability pairs. The study examined the effects of collaboration mode and group composition on individual posttest performance, group project performance, collaborative interaction behavior, and attitudes towards the instruction. The findings suggest that both virtual and face-to-face collaboration can be effective in achieving learning goals. However, consideration should be given to the collaborative structure of the lesson and the type of task in the design of computer-mediated collaborative environments.

Introduction

The use of the Internet and telecommunication technologies in education has increased in recent years with the proliferation of online learning. In 2002, more than two million college students were estimated to be enrolled in some form of web-based education. It is estimated that more than 90 percent of U.S. colleges and universities offered online options in 2005 (The Chronicle of Higher Education, 2005).

This movement towards online learning has prompted educational technologists to debate the most appropriate role for new technology (Golas, 2002) and motivated an educational paradigm shift from single-classrooms to knowledge-building communities of learners (Chou, 2001; Ravits, 1997). Advocates of computer-mediated collaboration (CMC) point to constructivism as the theoretical perspective for explaining its effectiveness (Kanuka & Anderson, 1998). Theorists suggest that learning is more effective when students are able to discuss their ideas, experiences and perceptions with peers (Jonassen & Kwon, 2001; Kanuka & Anderson, 1998). Some researchers have indicated that the flexibility and technological support for such interactions available in computer-mediated environments point to collaborative learning strategies as a promising means to implement new technology (Laffey, Tupper, Musser, & Wedman, 1998; Pena-Shaff & Nicholls, 2004; Strijbos, Martens, & Jochems, 2004; Oliver & Omari, 2001). Furthermore, theorists have indicated that CMC could have greater effects than other modes of interaction on learning in problem-solving, case study, and other higher-order learning situations (Adelskold, Alklett, Axelsson, & Blomgren, 1999; Johnston, 1996; Jonassen, Previs, Christy, & Stavulaki, 1999).

Researchers have shown that collaborative learning strategies in the classroom setting can positively affect learning outcomes, social skill development, and self-esteem (Johnson & Johnson, 1996; Slavin, 1990). Research also provides support for the use of collaborative learning strategies when students use computer-based instruction (CBI) (Cavilier & Klein, 1998; Dalton, Hannafin, & Hooper, 1989; Klein & Doran, 1999; Hooper, 1992; Hooper & Hannafin, 1991; Sherman & Klein, 1995).

Despite the positive findings for the use of collaborative strategies in CBI, there is little empirical evidence to indicate if the positive effects of collaborative learning on achievement transfer to environments where communication is mediated by computers. Much of the research on online learning has focused on student rates of participation and learner interaction (Macdonald, 2003; Pena-Shaff & Nichols, 2004; Sapp & Simon, 2005; Vrasidas & McIsaac, 1999). According to Hara (2002) and Murphy and Collins (as cited in Uribe, Klein, & Sullivan, 2003), research on synchronous CMC has been limited to surveys of students, investigations of the recreational use of online chat systems, and the use of these systems for instructional purposes has been explored only through case studies. Furthermore, among the studies that have examined achievement in the online environment, many consider only one collaborative condition rather than make a comparison of online to face-to-face situations (Berge, 1999; Brewer, 2004; Davies & Graff, 2005; Gunawardena & McIsaac, 2004; Hoskins & van Hooff, 2005; Laffey et al, 1998). Unless comparisons are made, it is difficult to determine the effect of computer-mediated collaboration (CMC) in virtual environments.
Another variable that may influence outcomes in collaborative learning settings is ability grouping. Ability grouping is the assignment of participants to small groups based on academic ability. Several studies have addressed ability grouping in face-to-face collaborative environments. However, there appears to be no single best way to divide students into learning groups. Some of these studies suggest that heterogeneous ability-groupings assist students of all ability levels with the acquisition of knowledge and the cognitive processing of this knowledge (Johnson & Johnson, 1996; Slavin, 1993). But other studies suggest that for the optimal development of thinking strategies and maintenance of self-esteem, group members should have similar cognitive abilities (Saleh, Lazonder, & De Jong, 2005).

Researchers who have advocated heterogeneous grouping by ability suggest numerous potential benefits for the higher-ability partners in these groups (Johnson, Johnson, & Holubec, 1996; Sharan & Sharan, 1992; Slavin, 1990). Heterogeneous groupings may support the academic achievement of high ability students by providing opportunities for deeper cognitive processing through the explanation of their own understanding to their partners. It is also suggested that higher-ability students acquire increased motivation and improved self-confidence. However, other studies have shown a negative or no impact on higher-ability students when paired in heterogeneous dyads (Hooper, 1992; Hooper & Hannafin, 1991; Sherman & Klein, 1995). Other studies suggest that homogeneous grouping may be the best when working collaboratively. Swing and Peterson (1982) found that students of average ability perform better in homogeneous groups than in heterogeneous groups. Hooper and Hannafin (1988, 1991) found that heterogeneous groupings have a negative impact on the achievement of higher-ability students. This is consistent with the findings of Sherman and Klein (1995) in which the confidence of higher-ability students was negatively affected by heterogeneous grouping.

Research also suggests that the efficacy of collaborative groupings is related to the interactions students exhibit when working in small groups. According to Sherman and Klein (1995), "Studies in which group member interactions have been recorded and analyzed indicate that achievement and attitude differences are related to the type and amount of verbal interactions between students" (p. 6). Webb (1989) reported that students in small groups who give or receive explanations during a lesson learn more from the lesson than those who do not. King (1989) found that small groups that asked task-related questions, discussed strategy, and elaborated solutions were more successful at problem solving than groups that did not exhibit these interaction behaviors. Gunawardena and Zittle (1997) noted that social interaction between learners could contribute to learner satisfaction and frequency of interaction in online or web-based instruction.

More recent research has shown that the mode of collaboration also impacts the frequency and quality of student interactions in collaborative environments. While some studies have found that participation and interaction is reduced in computer-mediated environments when compared to a face-to-face condition (Fahy, Crawford, & Aely, 2001; Vrasidas & McIsaac, 1999), much of the research has indicated that the quality of learner-learner interactions in a computer-mediated environment may actually be better than interaction in a face-to-face environment (Oliver & Omari, 2001; Sapp & Simon, 2005; Uribe et al, 2003).

The present study was designed to investigate the effects of two levels of collaboration mode (virtual or face-to-face) and the composition of groups (homogeneous higher-ability, homogeneous lower-ability, or heterogeneous mixed-ability dyads) within the context of computer-mediated instruction. Data on individual performance, group performance, attitudes, and time on task were collected for all participants. Data were also collected on the quality and frequency of learner-learner interactions in both the face-to-face and virtual collaborative condition. This study addressed the following research questions:

1. What is the effect of collaboration mode (virtual or face-to-face) on individual posttest performance, group project performance, attitude, and group member interaction in a computer-mediated, collaborative setting?
2. What is the effect of group composition (homogeneous higher-ability, homogeneous lower-ability or heterogeneous mixed-ability dyads) on individual posttest performance, group project performance, attitude, and group member interaction in a computer-mediated, collaborative setting?
3. What is the interaction effect of collaboration mode and group composition on individual posttest performance, group project performance, attitude, and group member interaction in a computer-mediated, collaborative setting?

Method

Participants

The participants for this study were 120 undergraduate preservice teachers enrolled in a computer literacy course at a state university in the northwestern United States. All participants were completing prerequisite requirements for entry into the upper division teacher certification program. The sample included students enrolled in six sections of the course. Participants were predominantly Caucasian female (69%), with a mean age of 22, from all major content areas.
The computer literacy course met twice a week for 75 minutes, and introduced basic technology skills in word processing, spreadsheets, databases, and presentation software. The Blackboard course management system was used as a supplement to face-to-face instruction in the course. Assignments were related to the basic function of each application, and face-to-face collaborative groups were often used during activities related to integration of technology into the classroom. In addition, this course prepared participants to take a state-mandated technology competency exam, which must be passed to receive credit for the course.

Materials

A computer-based instructional module on the basic functions of Microsoft Excel and the application of spreadsheets in the classroom was written for this study. It consisted of three parts: an introduction, a practice problem, and a group application project.

The program was specifically designed for use by collaborative dyads. Two scores contributed to the grade each student earned from the CBI lesson - one score was from a group application project each dyad completed as part of the program and the other score was from a posttest each individual completed at the end of instruction. Students were informed in the introduction that each score would contribute equally to their final score for the spreadsheet assignment.

The introduction contained 16 screens which provided information for students’ successful use of the program. It began with a brief demographic questionnaire, followed by instructions for using the program such as, where to click to advance to the next screen, and how to return to previous instruction. The introduction then presented a description of the collaborative nature of the lesson, the goals and objectives of the program, and an overview of spreadsheets, and encouraged students to help each other learn. A collaborative skills review reminded students to: give explanations when their partner asked for help, ask about their partner’s perceptions of the concepts, and wait to proceed through the instruction until their partner is ready. In addition, the review emphasized the importance of summarizing and listening when working collaboratively. The introduction concluded by informing students they would be learning about the basics of Excel, and would be required to develop a spreadsheet to solve some problems.

The practice problem component of the instruction consisted of 70 screens containing a classroom based scenario. Students assumed the role of a classroom teacher with the task of developing a class gradebook. The gradebook activity required students to determine several elements to include: class title, student names, assignments (homework, projects, quizzes, and exams), and the contribution of each assignment to the final grade. The gradebook would be formatted to calculate: student performance in each assignment category, student performance for the grading period, students’ final grades as a percentage and letter, the class average for each assignment, and the highest and lowest grades for each assignment. The gradebook would also include a graph. Completed gradebooks were then saved to each student’s network folder and the file path submitted to the researcher through the CBI, permitting the group to proceed to the group application project.

To encourage collaboration throughout the instruction, the practice problem was structured in two parallel tracks following a modified Jigsaw procedure (Aronson, Blaney, Sikes, & Snapp, 1978). Each track contained different skills required during the practice exercise so that one student could not receive all of the information necessary to complete the practice exercise independently. Once a student selected a track, they were unable to access the other track. This required each student to learn skills from, and teach skills to, their partner. Tracks were accessed by clicking the appropriate button.

Both tracks presented the student with a list of concepts and terms that should be defined and mastered. The tracks contained brief explanations and screen captures to illustrate the definition and function of each element in the instruction. Students were informed of the objectives and content within both tracks to ensure that all participants were aware of the skills required of the individual posttest. The program also contained a reminder that all of the skills included in both content tracks were required of the group application project.

A coder track, consisting of 32 instructional screens, covered the use of formulas and functions in Microsoft Excel. A designer track, consisting of 23 instructional screens, covered the formatting of a spreadsheet for efficient use. The remaining 15 screens were common to both tracks. These screens concluded the practice activity by providing instruction and practice on the Excel chart wizard.

The group application project consisted of a second spreadsheet activity, which required the same skills covered in the gradebook practice section. The group application project comprised the final seven screens of the CBI. No additional instruction was provided for this activity, but students were able to access their previous content track for review. Students had to determine on their own how best to complete the project. One application project was submitted per group.
Procedures

This study included six different treatment groups. Each of the six intact sections of the computer literacy course was assigned to either a face-to-face or virtual collaboration treatment condition. Using randomized block sampling within each class, participants were blocked by ability and assigned to dyads in one of three ability compositions (homogeneous low, homogeneous high or heterogeneous). Ability blocking was based upon performance on a general computer ability pretest. A one-way analysis of variance (ANOVA) conducted on the pretest scores showed no significant differences between class sections prior to the study, $F(5,136) = .08, p > .99.$ Due to the composition of each section, 38 students were assigned to higher-ability dyads, 40 to lower-ability dyads, and 42 to mixed-ability dyads. There were a total of 138 students at the beginning of the study. Data from 18 students were unusable due to absences during the study.

Dyads were given three, 75-minute class periods to complete the program and assessments. Student interactions were collected for each dyad during the first two days of the treatment by two trained research assistants. The frequency of these interactions were classified and recorded on an observation form.

On the first day of the treatment period, students in the face-to-face condition were verbally informed of their dyad assignments and asked to sit at a workstation next to their partner. Students were then asked to execute the installed CBI. Students in the virtual condition were informed they were participating in a simulation of a virtual environment, so all communication would take place using the synchronous chat feature of Blackboard. Participants in the virtual condition were not seated in proximity of one another or aware of each others’ identity until logging in to Blackboard. Participants in both conditions were instructed to run Microsoft Excel along with the CBI.

The second day of instruction was nearly identical to the first. Students in both conditions were asked to return to the workstation they used the previous class period and resume the lesson. Students in the virtual condition were again be reminded they had to login to Blackboard to communicate with their partner. At the conclusion of the second class period groups were required to submit their final projects. Any students finishing before the end of the period were excused.

An individual, computer-based, multiple-choice posttest covering the instructional material was administered to each student on the third day on instruction. Students also completed a Likert-type attitude survey, and five students from each treatment condition were randomly selected to participate in a short interview.

Data Collection Instruments

Six measures were used to collect data in the study. Participants completed a general computer ability pretest for assignment to ability groups. During instruction, student interactions were collected. Following instruction, participant performance was measured by a project scoring rubric and a posttest. Students also completed an attitude survey and interview after instruction.

Several weeks prior to the implementation of the study, a 25-item, computer-based, multiple choice pretest measuring general computer ability was administered to the participants. This pretest was used to determine student ability for assignment to dyads. The pretest contained five knowledge items from five of the test categories: the computing environment, word processing, presentation software, spreadsheets, and databases. Each pretest item was worth one point. All pretests were scored by the primary researcher.

A 25-item, multiple choice, computer-based posttest was administered during the week following the spreadsheet CBI. The test included items based on the program objectives, measuring knowledge and skills covered in the instructional program. Participants were required to identify various spreadsheet functions, terms, and the output of a given formula. Each posttest item was worth one point, and all posttests were scored by the primary researcher. The split-half reliability coefficient of the posttest was .88.

An attitude survey was developed to measure students’ reactions to the instruction. It contained 18, five-choice Likert-type items (4 – strongly agree, 0 – strongly disagree) and three open-ended questions. The survey included three sections, delivery system, topic, and collaborative work.

A six-item interview protocol was developed by the researcher to follow the attitude survey. Five participants from each treatment condition were asked both forced-response and open-ended questions related to their opinion of the program, the helpfulness of features of the program, and the perception of collaborative learning in each treatment condition.

The primary researcher developed a rubric to evaluate participant performance on the group project. Due to the nature of the problem, there was not a single correct answer. Therefore, students were evaluated on the inclusion of content, the accuracy of their calculations, and the format of their output. For inclusion of content, participants were evaluated on their efficiency in using the data provided. For accuracy of calculations, participants were evaluated on conducting the correct calculations and if all equations were accurate. For output, participants were evaluated on their clarity in formatting the spreadsheet. The group project spreadsheets were blind scored by one of two evaluators to prevent bias. Inter-rater reliability for a random sample of 15 student projects was .90.
Student interactions were collected for each dyad during the study using two different means. In the face-to-face condition, dyads were observed by trained research assistants. Each instance of collaboration was indicated on an observation form. Raters identified each dyad by number, but were unaware of the dyad’s ability composition to avoid any bias. Each dyad was observed in two minute intervals at various points throughout the program comprising a minimum of 20 minutes of observation during the instruction.

Interactions in the virtual condition were captured using the virtual classroom session log feature of Blackboard. The log files for each dyad were exported to a database for analysis by the primary researcher, and examined for the same collaborative behaviors as the face-to-face dyads. To ensure an equivalent comparison of interactions between the face-to-face and virtual dyads, time stamps for each interaction were used to reconstruct the class session on a timeline. Two-minute intervals were then systematically categorized to simulate the observations of the face-to-face dyads.

**Design and Data Analysis**

This study used a quasi-experimental, posttest-only control group design. It was a 3 (group composition: higher-ability dyads, lower-ability dyads, and heterogeneous dyads) by 2 (collaboration mode: face-to-face and virtual) factorial design.

Group measures were analyzed using analysis of variance (ANOVA) on group project performance. Individual measures were analyzed using ANOVA on posttest performance and separate 3 x 2 MANOVA’s on each factor of the attitude survey. ANOVA’s on each dependent variable were conducted as follow-up tests to the MANOVA’s. Follow-up univariate and Tukey HSD analyses were used where appropriate. To control for Type 1 error, each follow-up ANOVA was tested at the .01 level. Interaction frequency data were analyzed using Chi square analyses. Interview responses were categorized and reported by theme.

**Results**

**Posttest Performance**

Means and standard deviations for individual posttest performance are reported in Table 1. The mean posttest score for all participants was 18.15 (SD = 2.84) out of a possible score of 25. The mean posttest score was 18.69 (SD = 2.70) for students in the face-to-face collaborative condition and 17.57 (SD = 2.90) for students in the virtual collaborative condition. Table 1 also shows that the mean posttest score was 16.70 (SD = 2.30) for students in homogeneous lower-ability dyads, 18.40 (SD = 2.80) for students in heterogeneous mixed-ability dyads, and 19.39 (SD = 2.78) for students in homogeneous higher-ability dyads.

<table>
<thead>
<tr>
<th>Collaboration Mode</th>
<th>LL</th>
<th>HH</th>
<th>H/L</th>
<th>Total</th>
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<tr>
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<td>(SD)</td>
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<td>(3.20)</td>
<td>(3.12)</td>
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<td>n</td>
<td>18</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>Mean</td>
<td>16.70</td>
<td>19.39</td>
<td>18.40</td>
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<tr>
<td></td>
<td>(SD)</td>
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<tr>
<td></td>
<td>n</td>
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Note: The maximum score possible was 25 points.
LL = Homogeneous lower-ability dyads
H/L = Heterogeneous (mixed-ability) dyads
HH = Homogeneous higher-ability dyads
A 3 x 2 analysis of variance (ANOVA) was conducted to examine the effect of group composition and collaboration mode on individual posttest performance. ANOVA indicated a significant main effect for group composition, $F(2,114) = 10.79, p < .001$, partial $\eta^2 = .16$. Tukey HSD pairwise comparisons conducted as a follow-up to this main effect revealed that individual posttest scores for participants in homogeneous lower-ability dyads were significantly lower ($p < .01$) than scores for participants in the homogeneous higher-ability dyads and those in the heterogeneous mixed-ability dyads. There was not a significant difference between participants in the mixed-ability dyads and those in the higher-ability dyads.

ANOVA also indicated a significant main effect for collaboration mode, $F(1,114) = 6.43, p < .01$, partial $\eta^2 = .05$. Participants in the face-to-face collaborative condition significantly outperformed those in the virtual condition. ANOVA did not reveal a significant interaction between group composition and collaboration mode.

**Group Project Performance**

Means and standard deviations for group project performance are reported for dyads in Table 2. The mean project score for all dyads was 21.77 (SD = 1.91) out of a possible score of 24. The mean project score was 21.23 (SD = 2.01) for dyads in the face-to-face collaborative condition and 22.34 (SD = 1.59) for dyads in the virtual collaborative condition. Table 2 also shows that the mean project score was 20.65 (SD = 1.79) for students in homogeneous lower-ability dyads, 22.38 (SD = 1.66) for students in heterogeneous mixed-ability dyads, and 22.26 (SD = 1.85) for students in homogeneous higher-ability dyads.

<table>
<thead>
<tr>
<th>Collaboration Mode</th>
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<th>Standard Deviation</th>
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<td>HH</td>
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<td>10</td>
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<td></td>
<td>H/L</td>
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<td></td>
<td>22.34</td>
<td>(1.59)</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>Mean</td>
<td>20.65</td>
<td>(1.79)</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>22.26</td>
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</tr>
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<td></td>
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<td>21.77</td>
<td>(1.91)</td>
<td>60</td>
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</table>

Note: The maximum possible score was 24 points.

LL = Homogeneous lower-ability dyads
H/L = Heterogeneous (mixed-ability) dyads
HH = Homogeneous higher-ability dyads

A 3 x 2 analysis of variance (ANOVA) was conducted to evaluate the effect of group composition and collaboration mode on group project performance. ANOVA indicated a significant main effect for group composition, $F(2,54) = 5.85, p < .01$, partial $\eta^2 = .18$. Tukey HSD pairwise comparisons conducted as a follow-up to the main effect revealed that group project scores for dyads in homogeneous lower-ability dyads were significantly lower ($p < .01$) than scores for participants in the heterogeneous mixed-ability dyads and those in homogenous higher-ability dyads. There was no significant difference between the other group compositions.

ANOVA also indicated a significant main effect for collaboration mode, $F(1,54) = 5.93, p < .05$, partial $\eta^2 = .10$. Participants in the virtual collaborative condition significantly outperformed those in the face-to-face condition. ANOVA did not indicate a significant interaction between group composition and collaboration mode.
Student Attitudes

Attitude scores were based on a 5-point, Likert-type scale (4 – strongly agree, 0 – strongly disagree). These data indicated that most students felt the computer program was easy to navigate (M = 3.18, SD = .79) and that they are better prepared to use spreadsheets after completing the program (M = 3.01, SD = .76). Most students thought the spreadsheet is a useful tool to know (M = 3.61, SD = .54), and the spreadsheet skills learned will help in my career (M = 3.35, SD = .62). Students also generally liked their assigned partner (M = 3.25, SD = .81). However, students did not respond as positively to working with a partner over working alone (M = 1.84, SD = 1.28) and did not feel that they learned the material better working with a partner than they would have on their own (M = 2.25, SD = 1.28).

Three separate 3 x 2 multivariate analyses of variances (MANOVA) were conducted to determine the effect of group composition and collaboration mode on each of the attitude factors (delivery system, topic, and collaborative work).

MANOVA conducted on the items related to the delivery system indicated a significant main effect for collaboration mode, Wilks’s Λ = .74, F(7,101) = 5.17, p < .001. MANOVA did not show a significant main effect for group composition or an interaction between group composition and collaboration mode. Follow-up univariate analyses indicated a significant difference between collaboration modes on five of the seven items (p < .01). In all cases, students in the face-to-face collaboration mode responded more positively toward the delivery system than those in the virtual collaboration mode.

MANOVA conducted on the items related to the topic indicated a significant main effect for collaboration mode, Wilks’s Λ = .89, F(4,105) = 3.14, p < .05. MANOVA did not show a significant main effect for group composition or an interaction between group composition and collaboration mode. Follow-up univariate analyses indicated a significant difference between collaboration modes on two of the four items (p < .01). In both cases, students in the face-to-face collaboration mode responded more positively toward the topic than those in the virtual collaboration mode.

MANOVA conducted on the items related to collaborative work indicated a significant main effect for collaboration mode, Wilks’s Λ = .60, F(7,101) = 9.48, p < .001. MANOVA did not show a significant main effect for group composition or an interaction between group composition and collaboration mode. Follow-up univariate analyses indicated a significant difference between collaboration modes on five of the seven items. In all cases, students in the face-to-face mode responded more positively toward collaborative work than those in the virtual mode.

Approximately 91% of the study participants who completed the Likert portion of the attitude survey also responded to three open-ended questions. When asked what they liked best about the program, 24 of 96 respondents mentioned that the CBI was interactive. For example, a respondent indicated that they liked the program because, “It was interactive; we could move at our own pace. I could go back if I didn’t understand something.” Twenty-two participants mentioned the helpful practice, 16 mentioned the step-by-step presentation, and 16 mentioned the access to different tracks. When asked what they liked least about the program, 30 respondents indicated the inability to copy from the program into Excel, 24 participants mentioned using chat, and 16 responded working with a partner.

Finally, when asked about how to improve the program, 24 of 96 respondents indicated that the program could be improved by not using partners, 20 students wanted more practice in the program, 16 students mentioned not using chat, and 12 mentioned increasing the discussion of functions in the program.

Student Interviews

Five participants from each treatment condition were interviewed to determine their opinions of the program (n = 30). Participants were first asked about their opinion of the program. Fourteen of the 15 students in the face-to-face collaborative condition and 12 of 15 students in the virtual condition indicated they liked the program. Many responses were similar to the following:

I felt that the computer program was a good way to learn about spreadsheets. It not only taught the basics, but had us apply them at the same time. I liked it because it was informative, creative, and taught the basics of spreadsheets.

Other students said they liked the program because of the step-by-step presentation of information, or because students were required to teach what they had learned.

When asked about which parts of the program were the most helpful, 9 of 15 students in the face-to-face condition and 8 of 15 students in the virtual condition indicated the individual instruction component was the most helpful. Six students in the virtual condition said the practice project was the most helpful, while five students in the face-to-face condition mentioned the group project. When asked about which parts of the program were least helpful, seven students in the face-to-face condition and four students in the virtual condition indicated the inability to copy from the program into Excel was the least helpful component. Furthermore, four students in the virtual condition identified the Internet chat requirement as the least helpful.

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Responses to questions about working with a partner revealed that 10 of 15 students in both the face-to-face collaborative condition and the virtual collaborative condition liked working with a partner. One of the students in the face-to-face condition made the following representative statement:

I did prefer working with a partner; it was helpful to make sure I was doing things correctly, and for getting new ideas on our second project. I think the collaboration made things better for both of us because we were able to bounce ideas off each other.

A student in the virtual condition said, “It was fun to work with a partner in the spreadsheet lesson. I think it helped me better understand what I needed to know by having to explain it to someone else.” Conversely, 5 of 15 students in both the face-to-face and the virtual collaborative conditions indicated they did not like working with a partner. Students responding less positively towards working with a partner found it difficult to, “keep going back to explain what I just learned”, and indicated that working with a partner, “left a few gaps in my knowledge.”

When asked about how the lesson was used to learn about spreadsheets, 17 of 30 respondents said they simply followed the instructions. Five of the 15 students in the virtual collaborative condition mentioned that they relied on learning from their partner, while only 1 of 15 students in the face-to-face condition mentioned learning from their partner.

Finally, students were asked about their opinion of using a similar program in the future. Twelve of 15 students in the face-to-face condition and 11 of 15 students in the virtual condition indicated they thought it would be a good idea to use a similar lesson in the future. Three students in each condition thought that it should depend on the subject. For example, one student said, “I don’t think it would be useful for every application. It is really only good for basic procedural information.” Only one student indicated that they thought it would be a bad idea to use a similar program in the future.

**Student Interactions**

Interaction behaviors were grouped into the five categories of questioning, answering, encouraging, discussing, and off-task. Separate chi-square analyses were conducted to determine the effect of group composition and collaboration modes on the number of interactions for each category. No significant differences were found within any of the interaction categories between ability groups. However, chi-square analyses indicated that students in the virtual collaborative condition asked more questions of their partners, $X^2 = (1, N = 29) = 5.13, p = .025$, and exhibited more off-task interactions $X^2 = (1, N = 29) = 9.92, p = .01$, than those in the face-to-face collaborative condition. No other significant differences were found for interaction behaviors. The observed instances of student interactions that occurred during the instructional program are reported in Table 3.

**Table 3**

<table>
<thead>
<tr>
<th>Interactions</th>
<th>Group Composition</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HH</td>
<td>LL</td>
</tr>
<tr>
<td>Questioning*</td>
<td>120</td>
<td>145</td>
</tr>
<tr>
<td>Answering</td>
<td>90</td>
<td>98</td>
</tr>
<tr>
<td>Encouraging</td>
<td>51</td>
<td>39</td>
</tr>
<tr>
<td>Discussing</td>
<td>185</td>
<td>132</td>
</tr>
<tr>
<td>Off-task*</td>
<td>36</td>
<td>61</td>
</tr>
<tr>
<td>Total Interactions</td>
<td>482</td>
<td>475</td>
</tr>
</tbody>
</table>

Note: Total number of each interaction behavior for 60 dyads in 20 minutes of elapsed time observed in two-minute intervals.

LL = Homogeneous lower-ability dyads
H/L = Heterogeneous (mixed-ability) dyads
HH = Homogeneous higher-ability dyads
*p < .05 for mode

**Discussion**

This study examined the effects of collaboration mode and group composition on individual posttest performance, group project performance, student attitudes, and collaborative interaction behaviors. Students completed a collaborative computer-based program while communicating either face-to-face or by using
synchronous chat in a virtual, online setting. All participants were assigned to one of three group compositions based on general computer ability. These dyads consisted of homogeneous lower-ability, homogeneous higher-ability, or heterogeneous mixed-ability pairs.

**Performance**

Results indicated that participants in the face-to-face collaborative condition performed significantly better on the individual posttest than those in the virtual online condition. This finding likely occurred because face-to-face students found it easier to share information throughout the lesson than virtual students. This explanation is partially supported by results from the attitude survey which revealed significant differences in favor of students in the face-to-face condition for the following items: (1) I was able to adequately communicate with my partner; (2) My partner taught me what I needed to learn; (3) The checkpoints in the program helped my partner and me communicate; and (4) I liked the system for communicating with my partner.

Furthermore, observations of student interactions revealed that several face-to-face dyads used visual cues such as pointing to their screen to provide an explanation to their partner or to acknowledge understanding. Hara (2002) indicated that students are required to make assumptions about meaning when they collaborate in virtual environments because of a lack of visual cues obvious in face-to-face communication. Others suggest that student misconceptions may occur due to a lack of nonverbal interventions to signal misunderstandings and that students can become disoriented without visual anchors in a virtual environment (Ruberg, Moore, & Taylor, 1996; Sapp & Simon, 2005).

Observations in the current study also revealed that in a few instances, students in face-to-face dyads traded seats with their partner so that both students could work individually through each track, avoiding collaboration altogether. Slavin (1995) suggested that individual learning strategies are better than cooperative strategies when students are required to learn facts and procedures. The multiple-choice posttest in the current study required individual students to identify terms, spreadsheet functions, and the output of a given formula.

In contrast to findings for the individual posttest, dyads that collaborated virtually performed significantly better on the group project than those who collaborated face-to-face. The collaborative interactions of students in the virtual dyads likely influenced their scores on the group project. Observations conducted during the study revealed that dyads in the virtual condition exhibited significantly more questioning behaviors than dyads in the face-to-face condition. As the lesson progressed, the frequency of interaction increased for virtual dyads while it decreased for face-to-face dyads. Several students in the face-to-face condition were observed working independently on the group project.

Other researchers have found that student interactions influence learning and performance in collaborative settings. Hooper & Hannafin (1991) demonstrated that questioning contributes to learning in collaborative groups. King (1989) found small groups that asked task-related questions were more successful at problem solving than groups that did not exhibit such interaction behaviors. In a comparison of computer-mediated groups, Sherman and Klein (1995) reported that dyads exhibiting more helping behaviors such as asking and answering questions performed better than dyads exhibiting significantly fewer helping behaviors.

The interaction requirements for an inquiry type project, such as the group project in this study, may be better met by virtual collaboration than face-to-face. Theorists have discussed advantages of virtual over face-to-face collaboration for group problem-solving tasks. Jonassen et al. (1999) asserted that CMC environments are better suited for problem-solving activities. The process of writing and reflecting may encourage higher level learning such as analysis, synthesis, and evaluation, and promote clearer and more precise communication (Garrison, 1997; Jonassen & Kwon, 2001). A study by Uribe et al. (2003) found that computer-mediated groups experienced performance benefits from the medium when performing an ill-structured problem solving task.

In addition to the findings for collaboration mode, group composition had a significant impact on individual posttest scores and group project performance in the current study. As expected, students assigned to higher-ability dyads performed significantly better on both performance measures than students assigned to lower-ability dyads. Furthermore, mixed-ability dyads performed significantly better on both performance measures than students assigned to lower-ability dyads.

**Student Attitudes**

Turning to attitudes, participants were generally positive about the delivery system and topic of the computer-based program used in this study. However, attitudes toward collaboration were less positive. Most of the Likert-type survey items asking about collaborative work were rated lower than items about the delivery system and the topic. Furthermore, open-ended survey items revealed that many students disliked working with a partner and thought the program could be improved by eliminating collaboration.

These results likely occurred because the collaborative structure used in the study placed too many limitations on students’ ability to interact naturally, especially for those in the virtual collaborative condition.
Results indicated that students in the virtual condition were significantly less positive than students in the face-to-face condition toward the delivery system, the topic, and collaborative work, with significant differences occurring on 12 of the 18 Likert-type items. Open-ended items revealed that half of the respondents in the virtual condition identified communicating via synchronous chat as the thing they liked least about the program. In addition, almost one-third of the virtual students who participated in follow-up interviews cited the chat system as the least helpful part of the program.

These findings are consistent with results from other studies. Uribe, et al. (2003) found that participants did not like virtual collaboration due to the difficulties of communicating via computer. Others have reported that students in virtual groups were less satisfied than those in face-to-face groups with instruction received from their partner (Olaniran, Savage & Sorenson, 1996: Warkentin, Sayeed, & Hightower, 1997).

Student Interactions

As discussed above, virtual dyads were observed to have significantly more questioning behaviors than face-to-face dyads. In addition, virtual dyads exhibited significantly more off-task interactions than face-to-face dyads. Many studies have detailed the importance of social interaction in computer-mediated communication (Chen, 2005; Jung, Choi, Lim, & Leem, 2002; Savenye, 2005). Anderson and Harris (1997) identified that socially oriented factors contribute to the prediction of performance in computer-mediated settings.

It is likely that the increased off-task behaviors for virtual dyads are a result of the necessity to establish a virtual social presence. It is interesting to note that while group composition did not have a significant effect on interaction behaviors, mixed ability groups exhibited the highest number of off-task interactions. Perhaps heterogeneous groups have a greater need than homogeneous groups to establish a social presence.

Implications and Future Research

The results of this study have implications for the design and delivery of computer-mediated instruction in collaborative environments. Findings suggest that both face-to-face and virtual collaboration can be effective in achieving learning goals. However, consideration should be given to the type of learning task and the collaborative structure of the lesson when designing computer-mediated instruction. Face-to-face collaboration may be better suited than virtual collaboration to environments where the acquisition of well-defined facts and procedures is desired. Furthermore, virtual collaboration may be better suited than face-to-face collaboration when solving ill-structured problems is the desired outcome.

It should be noted that results were obtained in an environment constrained by a rather rigid collaborative structure. Yet to be resolved is the question of what kind of collaborative structuring should be used to support positive outcomes in computer-mediated environments. Theorists have argued that ill-structured tasks are best addressed in open-ended environments and that well-defined tasks are better addressed in more rigid environments (Jonassen, et al., 1999; Jonassen & Kwon, 2001). However, the results of this study seem to indicate that task type and structure are mediated by the mode of collaboration.

The current study also suggests that group composition should be considered when forming collaborative dyads. Regardless of the mode of collaboration, pairing two lower-ability students has a negative impact on learning facts and procedures and on solving problems. Results also confirm findings of other researchers who suggest lower-ability students may benefit from being paired with higher-ability students (Saleh, et al., 2005; Slavin, 1993; Uribe et al., 2003).

The interdependence of design considerations such as collaborative structure, task and collaboration mode should be further explored. Additional research is needed to determine whether a particular collaborative structure is better suited for certain types of tasks in a CMC environment, or if certain tasks are inappropriate for computer-mediated collaboration. As stated by Salomon (1999), “The fact that something is technologically possible does not imply that it is also educationally desirable” (p. 36). Research should identify the most effective instructional practices to promote the learning of various skills. Future research could also address the method for forming groups in online and face-to-face collaborative settings. Factors such as group size should be explored to determine an optimal size for learning in computer-mediated collaborative environments.

As the demand for online and distance education expands, more students will be required to work collaboratively to learn from computer-mediated instruction. The production of increasingly complex tools for virtual collaboration will challenge practitioners to implement the most effective strategies for learning. Educational technology researchers should continue to examine the factors that impact learning when students use web-based and computer-mediated instruction in collaborative environments.
References


