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Computer-supported collaborative learning performance and satisfaction: A multi-stage study

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ABSTRACT

Research in computer-supported cooperative learning provides evidence that collaborative technology can enhance learning performance and increase affective experiences in the context of cooperative learning. Most studies, however, have examined the learning performance only during the middle and end of the process. It is not clear how information technology continuously facilitates and improves student performance and learning experience over time. By employing a multidisciplinary approach, the research presented in this article drew research findings in the fields of communication, information systems, and education to examine cooperative learning processes with a continuous, longitudinal study.

Based on a descriptive model of computer-supported cooperative learning, this research examined the effect of a collaborative technology on the accumulation of learning performance and learning satisfaction on group members. Three sets of hypotheses regarding learning performance, perceived learning performance, and group member satisfaction are examined.

INTRODUCTION

Computer-Supported Collaborative Learning (CSCL) is the use of collaborative information technologies (IT) in cooperative learning processes (Alavi, 1994; Brandon & Hollingshead, 1999; Koschmann, 1994; Leidner & Jarvenpaa, 1995). CSCL is aimed to facilitate better learning effectiveness and experience by creating synergy between cooperative learning methods and collaborative technologies. Collaborative technologies could assist learning by equipping students with various capabilities, such as concurrent information sharing, real-time feedback, and a

variety of computational tools. Cooperative learning methods could provide the capability of group structuring support to a computer-supported learning environment. Leidner and Jarvenpaa (1995) theorize that in the domain of business education, methods and technologies that can facilitate student interaction and involvement are preferred to traditional methods in improving the quality of business education.

Research in CSCL (either synchronous or asynchronous) shows that with few exceptions, students in computer-supported environments (Alavi, 1994; Alavi, Wheeler, & Valacich, 1995; Alavi, Yoo, & Vogel, 1997; Althaus, 1997; Hiltz, 1993; Hiltz & Wellman, 1997) tend to perform, as well as or better academically than those without computer support. However, it is not clear how IT facilitates cooperative learning. For example, Alavi (1994) and Althaus (1997) found significant differences in final exams, but not in the midterm exams between students with computer support and those without computer support. The question then arises: How does the better performance of computer-supported students develop during the semester? In addition, what is the trajectory of performance improvement among computer-supported students, and what is the critical point beyond which the difference in performance between groups in the two conditions becomes significant? Answers to these questions cannot only improve our understanding of how IT facilitates learning over time, as suggested by several researchers (Alavi, 1994; Leidner & Jarvenpaa, 1995), but they can also help instructors who intent to adopt similar pedagogical methods to plan their use of IT in their classes. This study is aimed to answer the above questions by revealing the dynamics of computer-mediated learning processes over time.

By drawing on research in information systems (e.g., Alavi, 1994; Leidner & Jarvenpaa, 1995), communication (Hiltz, 1993; Brandon & Hollingshead, 1999), and education (Slavin, 1991), this study examined how collaborative technology enhances learning, as well as promotes satisfaction. This was done by examining the differences in learning performance, satisfaction with the communication mode, and perceived learning performance among students in a face-to-face (FtF) collaborative learning environment compared to students in a computer-supported collaborative learning (CSCL) environment over the course of one semester. Most previous studies have only observed learning groups during the middle and end of the school semester. This study differs from others in that it is longitudinal, with continuous observations of performance and satisfaction made throughout the semester.

PRIOR RESEARCH

CSCL may take place in three different forms. The first form occurs in a classroom setting in which students learn together by following one cooperative learning method. Collaborative technologies are then employed to supplement the cooperative learning method process (Alavi, 1994; Hiltz, 1993; Koschmann, 1994). The use of IT in this setting is intended to enhance the benefits brought about by the cooperative learning method. Research shows that students with the support of collaborative technology perform academically as well as or better than those without support (Alavi, 1994; Hiltz, 1993). Students with computer support also reported a higher level of satisfaction with the learning process than did those without support.

Another form of CSCL (Alavi, Wheeler, & Valacich, 1995; Alavi, Yoo, & Vogel, 1997; Wheeler, Valacich, Alavi, & Vogel, 1995) occurs in inter-institutional settings in which students in two or more institutes at geographically different places learn from one another via a collaborative process with the help of a variety of collaborative technologies, such as teleconferencing and videoconferencing. The main objectives of this type of CSCL are to gain an understanding of how inter-organizational teams can be supported with advanced information technology in general and to examine the efficacy of emerging collaborative technologies as pedagogical tools in particular. This type of CSCL is usually conducted synchronously with student teams, multiple instructors, and external expertise. While participating universities could be paralleled in terms of size and academic reputation, they might be quite different in many aspects: curricula, scheduling, and student backgrounds (Wheeler, Valacich, Alavi, & Vogel, 1995). Students in this form of CSCL can then benefit from the exposure to different perspectives and external knowledge. Previous research shows that students' performance in knowledge acquisition in this type of CSCL is not significantly different from that in face-to-face cooperative learning (FTFCL) environments, but they acquire better critical thinking skills and are more satisfied with the process (Alavi, Wheeler, & Valacich, 1995).

The third form of CSCL occurs in the setting of online groups in which cooperative learning methods are employed to guide group discussions or to impose structure onto online groups (Brandon & Hollingshead, 1999; Hiltz, 1993). One of major features of computer-mediated communication (CMC) that differentiate it from traditional communication media is its many-to-many communication mode. This feature not only makes it possible to implement broadcasting type of distance learning, but also lends itself to online groups in which teaching materials can be disseminated and students' perspectives and ideas can be shared. Online group setting gives students greater access to their professors, multiple perspectives from their peers, and longer time to contemplate the issues before they respond (Hiltz & Wellman, 1997). However, when teaching through the use of CMC, one may encounter many hurdles, such as students' discernment of when and how to use the technology, wide variance of student expertise, specialization of technology, and perceived relevance (Witmer, 1998). The use of collaborative learning methods within online learning groups can make the discussion process more structured and potentially overcome the above hurdles while maintaining the benefits from the use of computer-mediated communication media in instructional settings.

Collaborative technologies used in previous studies varied from asynchronous textual communication media (e.g., e-mail and electronic bulletin boards [in Althaus, 1997]) to synchronous audiovisual communication media (e.g., desktop videoconferencing [in Alavi, Wheeler, & Valacich, 1995]) to group support systems that feature group techniques, such as brainstorming (e.g., group decision support systems [in Alavi, 1994]). A distinguished characteristic shared by those studies is that they were intended to contrast and compare the effects of different communication media. Griffith and Northcraft (1994) refer this type of research design as Type I and claim,

Type I across-media research designs confound features with media. The typical Type I comparison compares the effects of the usual constellation of features in one medium to the effects of the usual constellation of features in a second me-

dium. This research design may attribute to media consequences which are, in fact, the effects of features. (Griffith & Northcraft, 1994, p. 274)

Although there is a general agreement among CSCL researchers that the more groupware options are provided to on-line groups, the more productive they will become (Brandon & Hollingshead, 1999), the above observation by Griffith and Northcraft (1994) has a profound implication to the extant CSCL research that "the accepted effects of a medium should be re-examined in light of the medium's component features" (p. 272). Comparison of different features in one medium could help to pinpoint the exact feature in the medium that causes the effect that previously was roughly attributed to the medium. It would also improve the understanding of relationship between features and effects. It should be noted that channels are medium features, but features include more than channels (Griffith & Northcraft, 1994). Examples of channels include face-to-face, video, audio, synchronous electronic chat system, and electronic mail, while other features may include various analytical tools for modeling and problem solving. DeSanctis and Gallupe (1987) classified group support systems into three levels by collaboration support features: Level 1 technologies are those that remove communication barriers and facilitate information exchange among members. Technologies of Level 2 offer decision modeling and analytical techniques that could assist members to make better decisions. Level 3 technologies incorporate rules that regulate communication channels, contents, and timing of information exchanges. While research in the area of group support systems has taken into account the effect of difference in system features on the group performance, it appears that research in CSCL seems to have failed to differentiate features from the medium. Since this research is aimed to reveal the dynamics of CSCL, based on the above discussion, the study adopted a Level 1 system in order to reduce the confounding effect of features with the medium itself.

THEORETICAL FRAMEWORK: HYPOTHESES

The theoretical foundation of this research is adapted from the descriptive model of CSCL proposed by Brandon and Hollingshead (1999). Synthesized from three different models of group effectiveness, the descriptive model describes CSCL theory and research in the form of input-process-output. This model suggests that CSCL outcomes (positive academic and affective results) are the results of CSCL behavioral and cognitive processes, which, in turn, are the results of social-behavioral variables, social-cognitive variables, fit of course and CSCL, and student variables. The effects of input variables on behavioral and cognitive processes are moderated by technological and instructional variables. The model is shown in Figure 1.

Although it is barely mentioned in the CSCL research, task type is widely considered by group support systems (GSS) researchers as one of the most significant factors affecting group outcomes and processes (Fjermestad & Hiltz, 1999). In order to reduce the varying effects of different tasks types, the learning activities performed by students in the research are structured so that they all belong to the same category. Specifically, the task type of learning activities is intellectual in nature, according to McGrath's Task Circumplex (1984).

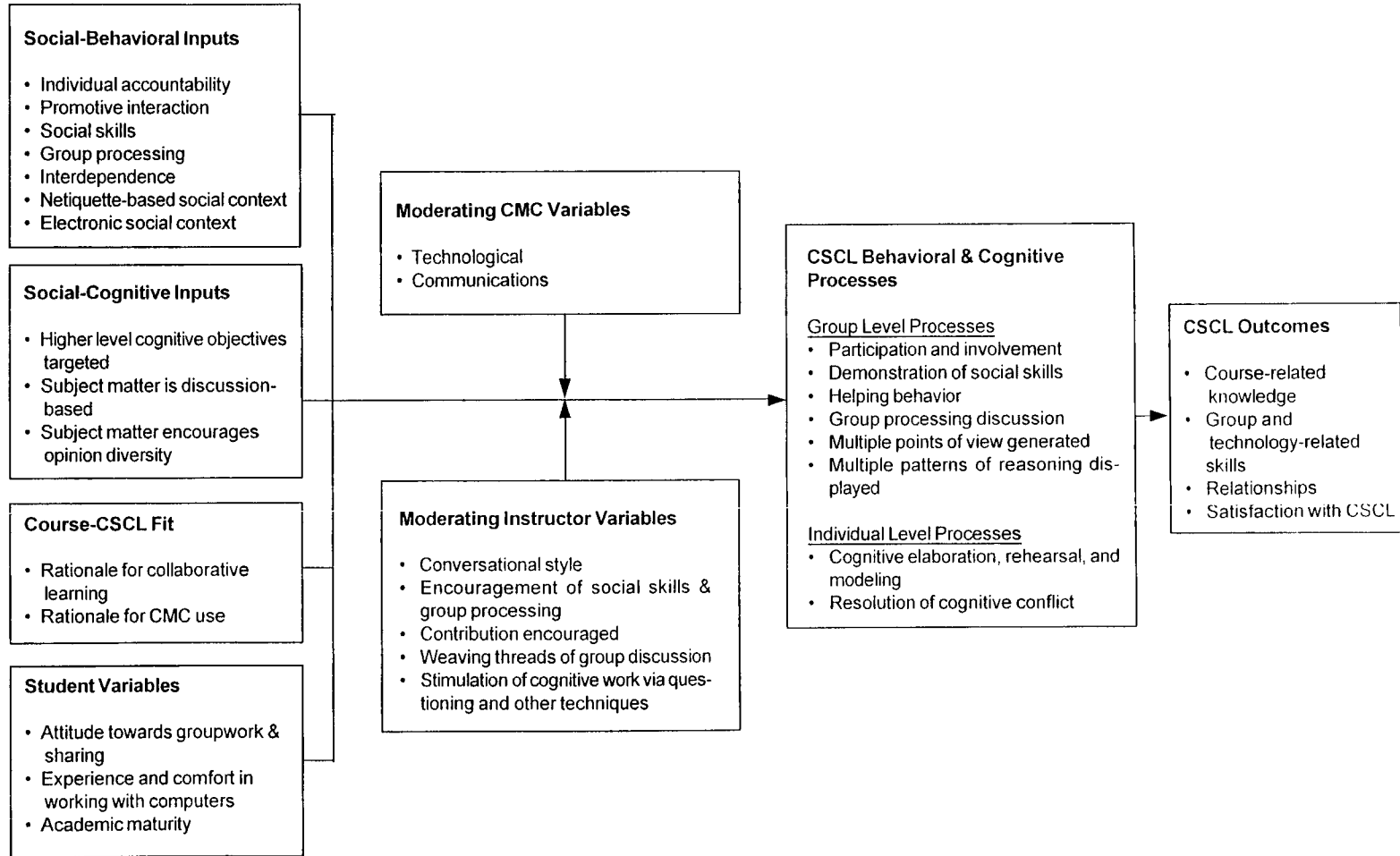


Figure 1. A Descriptive Model of CSCL Theory and Research (Source: Brandon & Hollingshead, 1999)

Group size is another group characteristic that has significant effects on group performance (Fjermestad & Hiltz, 1999) and, subsequently, it could influence group learning effectiveness. However, the findings of previous research regarding the group size effect is mixed. An assessment of GSS experimental research (Fjermestad & Hiltz, 1999) shows that small-size groups (about three to five subjects) could obtain the same number of positive effect (CMC groups performed better than FtF groups) as that of negative effect (FtF groups performed better than CMC groups) (Fjermestad & Hiltz, 1999). Medium-size groups (about six to ten subjects) would have less positive effects than negative effects. Interestingly, large-size groups (ten or more subjects) had much more positive effects than negative effects. Since most of cooperative learning methods suggest small-size groups and small-size groups, among others, would increase the experiment power, the present study used groups of three each.

The learning effectiveness consists of two parts: academic and affective outcomes. Academic outcomes refer to the mastering and perceived mastering of learning materials, while affective outcomes mean subjectively measured satisfaction with the process or with the academic outcomes. Academic outcomes are traditionally the focus of evaluation when comparing computer-mediated (CM) learning environments to traditional learning environments (Hiltz, 1993). The majority of previous research (Alavi, 1994; Althus, 1997; Hiltz, 1993; Hiltz & Wellman, 1997) suggests that students in CM environments tend to have better mastery of learning materials. Research by Alavi (1994) and Althaus (1997) further indicates that students in CM groups have significantly higher performance for final exams than students in FtF groups, but no significant differences in midterm exams. Possible explanation for this finding can be found in communication research. Hollingshead, McGrath & O'Connor (1993) assert that the performance of group members working together is affected by the level of their familiarity with the communication medium. This suggests that students in CM groups would not perform as well as their counterparts in FtF groups until they are familiar with the medium. As the semester proceeds, students in CM groups should become more proficient with the use of the CM medium and, consequently, their performances should improve. This proficiency might be further strengthened, as suggested by Adaptive Structuration Theory (Poole & DeSanctis, 1989), by students' manipulating structural features of the technology. It is believed the strengthened proficiency, in turn, will improve students' learning performance over time. As a result, we summarize our hypotheses regarding learning performance as follows:

- H1:** Learning performance differences between CSCL and FTFCL groups will not be consistently significant during the entire semester.
- H1a:** There will be no significant performance differences in the early sessions between CSCL and FTFCL groups.
- H1b:** CSCL groups will perform significantly better than FTFCL groups in the later sessions.

Students in FtF environments tend to be more satisfied with the process than students in CM environments (Benbunan-Fich & Hiltz, 1999). The lower level of satisfaction in CM groups might be attributed to the lack of facial expressions and to members' unfamiliarity with the

medium (Hollingshead, McGrath & O'Connor, 1993). However, members in CM environments tend to indulge in more task-oriented conversation (Bordia, 1997) and greater achievement might be accomplished, which in turn may positively affect the satisfaction with the learning process. Additionally, as suggested by the Adaptive Structural Theory (Poole & DeSanctis, 1989), students in CM groups over time might adapt structures in the medium to fit the context of their learning environment in a way that best suites them. As a result, the difference in satisfaction between CM groups and FtF groups over time may diminish.

- H3:** No consistently significant differences in group member satisfaction will be found between CSCL and FTFCL groups for the entire semester.
- H3a:** Group member satisfaction with the CSCL environment will be lower than those with the FTFCL environment in early sessions.
- H3b:** There will be no significant difference in satisfaction between CSCL groups and FTFCL groups in later sessions.

RESEARCH METHODS

Participants

One hundred and nineteen undergraduate students who were enrolled in three sections of a one-semester-long course on Production and Operations Management were recruited to participate in this study. Participation in the study is one of two optional, partial requirements for the course. Students could choose participating in the project or choose finishing an individual project with equivalent workload. All three sections were taught by the same instructor with the same textbook, teaching materials, coverage, examinations, and requirements.

In order to reduce possible bias in the measurements, a great deal of care was taken in the instruction and the assignment of subjects into the two conditions. Because the majority of subjects had full-time jobs, it was plausible that their preference for one particular time period might interfere with the proceedings of learning activities. As a result, subjects in each of the three sections were randomly and evenly assigned to either the CSCL environment for the FTFCL environment, and then those in each condition were randomly assigned to form groups of three. That is, instead of assigning students in one section to one condition and students in another section to the other condition, students in one section were evenly and randomly assigned to the two conditions.

Each condition had 20 groups of three each (except one CSCL group which had 2 group members)—59 students in the CSCL condition and 60 students in the FTFCL condition. Each subject was asked to read and sign a consent form and to fill out a preliminary questionnaire. Participants in both conditions stayed in the same team throughout the whole semester. The gender breakdown of subjects is listed in Table 1. The average age of the subjects is 25.89. About eighty percent of students had full-time jobs.

Table 1. Gender Breakdown of Subjects

	CMC	FTF
Female	28	29
Male	31	31

Research Design and Procedure

The research used in a multivariate repeated-measures design. The experiments were conducted biweekly over the course of one semester. In total, six experiments were done. No specific job divisions were assigned to individual team members. The meetings of CSCL groups were held in a computer laboratory with 24 PCs, each of which was equipped with a synchronous communication program (ICQ™). One week ahead of the first experiment, subjects in the CSCL groups were introduced to the operation of the system and all subjects in the two conditions were briefed as to the purpose and procedures of the research. An experiment protocol was prepared and announced to subjects in both conditions.

The collaborative learning process used in this study was adapted from Student Team-Achievement Division (STAD) (Alavi, 1994; Slavin, 1990): Lecture, peer learning, and evaluation. Lecture was done in the classroom and then cooperative learning was held in the lab (CSCL) or the classroom (FtFCL). The meetings lasted fifty minutes and proceeded as follows: Each team member studied the case on his/her own for fifteen minutes and took notes of his/her ideas about the case. In the following thirty-five minutes, team members discussed the case, exchanged their ideas, and reached their conclusion about the case. All subjects in the two conditions were required to take a quiz based on the contents covered in the teaching period and to answer the questionnaire.

Dependent Variables

Three dependent variables were examined in the study: academic performance, students' perceived performance, and students' satisfaction with the process. Learning performance was measured with quizzes consisting of multiple-choice questions. The questions were to test students' mastery and application of concepts in the case. The perceived learning performance measured the subjects' estimate of how much they learned within different conditions. Perceived learning performance was measured by items adopted from previous research (Alavi, 1994; Hiltz, 1993). The satisfaction measure used in this study was derived from Olaniran (1996), which measured group satisfaction within computer-mediated and face-to-face environments.

Learning Cases

To assess the degree of learning for both conditions in this study, six scenario cases were used. These cases were taken and modified from the textbooks of Production and Operations

Management by William J. Stevenson (1999) and by Barry Render and Jay Heizer (1996). Each case described a scenario in which the decision-maker needed to make a plan or reach a decision, which would be considered an intellectual task according to McGrath's Typology of Tasks (1984).

The cases included the background of the scenario, the problems and/or the opportunity the decision maker faces, and the requirements for an acceptable or feasible solution. Also, two or three questions were included in each case to guide students' discussion. Those questions were general enough for team members to propose various ideas and directional in nature in that multiple solutions were possible.

RESULTS AND DISCUSSION

The General Linear Model in SPSS for Windows was used to perform multivariate repeated measures analysis for the test hypotheses regarding the three dependent variables: performance (H1), perceived performance (H2), and satisfaction (H3). Where interaction effects were found, MANOVAs were performed on the dependent variables in the early sessions or late sessions (i.e., simple effects of the factor time) (Keppel, 1991). All analyses were conducted at the significance level of 0.05.

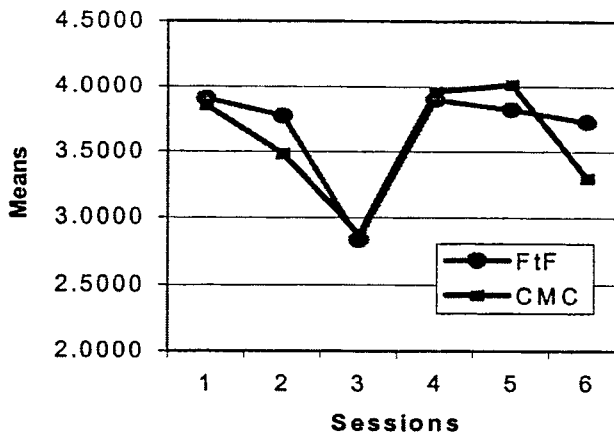
Learning Performance

H1 predicted that difference in learning effectiveness between CSCL and FTFCL groups during the entire semester would not be consistently significant. This hypothesis was accepted [$F(5, 34) = 12.66, p < 0.05$]. The hypothesis suggests that the difference in performance between CSCL and FTFCL varies from session to session. However, the direction of variation was not indicated. Hypotheses H1a and H1b, considered together, would reveal the direction of changes in learning effectiveness. H1a predicted that there would be no significant differences in learning effectiveness in the early sessions between CSCL and FTFCL groups. As there lacks evidence to show the difference between both conditions [$F(5, 34) = .35, p > 0.05$], it is fair to say that the result is consistent with the prediction derived from the findings of research in the fields of communication and information systems. It was also hypothesized (H1b) that CSCL groups, after adjusting to their environment, would increase their level of performance and outperform the FTFCL groups in later sessions. In other words, the learning performance of CSCL groups would be better than that of FTFCL in later sessions. H1b was not supported [$F(5, 34) = .114, p > 0.05$]. Despite this outcome, except for the last session, the CSCL groups did slightly outperform their counterpart in the FTFCL environment in most sessions. Though, as seen in Figure 2, there was a certain level of consistency in learning effectiveness between both the CSCL and FTFCL groups. It implies that the medium might not have significant impact in the final performance. A post hoc comparison of final grades of students in these conditions confirmed the implication. There are several possible explanations for the result: One is that the better performance of CSCL groups found in previous studies (e.g., Alavi, 1994) could be attributed to additional features, rather than the medium itself, of the technology used by students. For ex-

ample, the technology used by students in the study conducted by Alavi (Alavi, 1994) is a system of Level 2 GDSS. The difference between Level 1 and Level 2 GDSS might be responsible for the discrepancy in results between previous studies and the present research. Second possible explanation is related to relatively small group size. According to suggestions specified by Student Team-Achievement Division (Alavi, 1994; Slavin, 1990), this research formed groups of three students, while tools of Level 1 GDSS are most beneficial to groups of large-size (more than ten members per group) (Fjermestad & Hiltz, 1999).

An interesting finding is that the performances of groups in these two conditions declined and then rebounded about in the middle of the semester. There is one possible explanation for the unexpected finding. According to Gersick (1988), group development follows a punctuated equilibrium model. Groups alternated relatively stable periods of activity. Transitions from one period to another were punctuated by significant changes in group member behavior, which in turn are triggered by the realization of time pressure and the deadlines. The poor performance of both groups in the third session and rebound in the fourth session might be due to students' awareness of the approaching of the end of the semester.

Figure 2. Profile Plot of Learning Performance Over Time

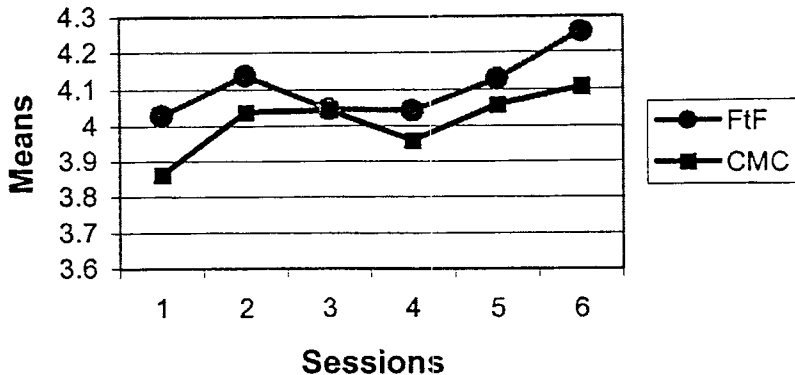


Perceived Performance

H2 predicted that difference in perceived learning performance between CSCL and FTFCL groups during the entire semester would not be consistently significant. Perceived performance was measured at the end of each group session, using a three-item semantic differential scale with a reliability of (Cronbach's α) of 0.89. This hypothesis was accepted [$F(5, 34) = 2.729, p < 0.05$]. In order to pinpoint the direction of variation, H2a predicted that there was no significant difference in perceived learning performance in the early sessions between CSCL and FTFCL groups. Since there is no evidence to indicate the existence of difference between these two con-

ditions [$F(5, 34) = .62, p > 0.05$], it appears fair to say that the result is consistent with the prediction. Nevertheless, the hypothesis (H2b) that CSCL groups would have significantly higher perceived learning performance than FTFCL groups in the later sessions was not supported [$F(5, 34) = .56, p > .05$].

Figure 3. Profile Plot of Percieved Performance Over Time



As the profile plot in Figure 3 shows, perceived performance in both the CSCL and FTFCL groups are generally increasing, with FTFCL groups for the most part having higher levels of perceived performance. This suggests that over time, both groups become accustomed to their learning environments and consequently develop a greater confidence in their performances. However, it is believed that the FTFCL groups start off with and generally continue to have greater perceptions of learning performance because of the immediate feedback nature, as well as greater range of cues that are associated with FtF environments as opposed to CM environments. The result is different from previous studies (e.g., Alavi, 1994; Althaus, 1997). The discrepancy might be attributed to different technologies used in the present research and previous studies. In Alavi's study (1994), tools of Level 2 GDSS were used, while the present study adopted Level 1 technology. The novelty and sophistication of Level 2 collaborative technologies might significantly affect the subjects' perception. Additionally, asynchronous communication mode of the medium adopted in Althaus's study gave students more time to contemplate issues in question before they responded. In other words, time constraint in the present research might account for the difference between Althaus's findings and the result in the research.

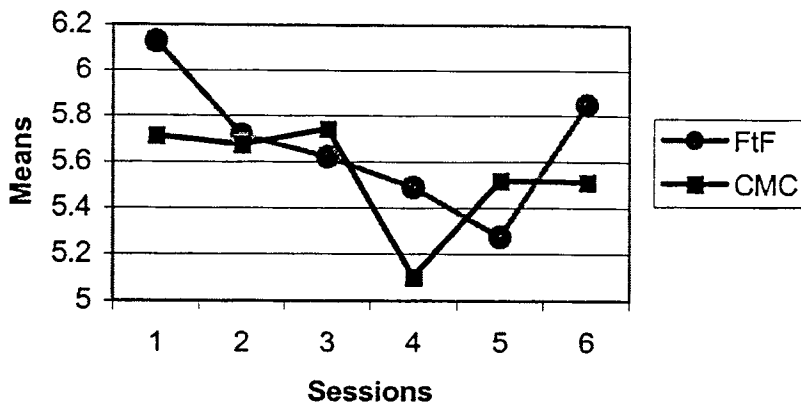
Satisfaction

Satisfaction with the learning process was measured after each group session, using a seven-item semantic differential scale, adapted from Olaniran (1996). A Cronbach Alpha Coefficient of 0.899 for the scale was obtained. H3 stated that no consistently significant differences

in group member satisfaction would be found between CSCL and FTFCL groups for the entire semester, which was accepted [$F(5, 34) = 5.416, p < 0.05$]. However, H3a, which stated that group member satisfaction with the CSCL environment would be lower than the FTFCL environment in early sessions was surprisingly not accepted [$F(5, 34) = .47, p > 0.05$]. Nevertheless, a t-test showed that there was significant difference in satisfaction between both conditions in session one ($p < 0.05$), as shown in the profile plot (Figure 4).

Hypothesis H3b predicted that there would be no significant differences in satisfaction between CSCL and FTFCL groups in later sessions, after the CSCL groups have adapted to their environment. Since there is a lack of evidence for the difference between both conditions in late sessions [$F(5, 34) = .46, p > .05$], it appears that the result is consistent with the prediction.

Figure 4. Profile Plot of Satisfaction Over Time



The profile plot of satisfaction over time (Figure 4) indicates that the differences in satisfaction between groups were not consistently significant. Nevertheless, the satisfaction level of CACL groups was lower than FTFCL groups in the two first sessions, confirming the findings of previous research (Hollingshead, McGrath & O'Connor, 1993). After the second session, the FTFCL and CSCL groups had no consistent pattern. The cause for this discontinuity of the pattern needs further investigation.

LIMITATION OF THE RESEARCH AND CONCLUSION

The strength of the study lies in its continuous multiple measurements of students' learning performance over the course of one semester. Multiple measurements provide a basis for evaluating the effects of time and to its interaction with technology support on academic performance

and affective outcomes. This would resolve the issue of whether the effect of technology support on learning is transient or sustainable. Additionally, the quasi-experimental setting adopted by the present study could increase external validity of the findings. However, these benefits were not obtained for free. Just like similar research in this area, a decision over the trade-off between rigor and realism must be made. Because the study was conducted over a period of twelve weeks, the time was long enough for students to become acquainted with each other outside the experimental sessions. Positive or negative relationships developed from this acquaintance might affect students' performance and satisfaction.

Furthermore, the research intently adopted a technology of Level 1 GDSS so that technology features could be differentiated from the medium itself. This might account for the difference in findings between the research and previous studies. Future research could take into account the effect of technology level by incorporating it as a factor. Also, research in GSS shows that the group of large size (more than ten members) would benefit most from the use of GSS; however, following the suggestion of cooperative learning method (i.e., STAD [Alavi, 1994; Slavin, 1990]), the research used small-sized groups. This might be responsible for the less significant difference in learning performance. As a result, it appears fair to reason that the synergy between cooperative learning and collaborative technology could be increased in large-sized classes in the long term.

This study compared traditional, FtFCL environments to CSCL environments for differences in students' learning performance. To do this, this study continuously measured academic performance and subjective assessment of satisfaction with the learning environments during the course of one semester. The results show that the learning performance differs across the media over time. However, the difference in learning performance is not consistently significant. Furthermore, students in FtFCL environment were more satisfied with the process than those in CSCL environment at the beginning of the semester; however, there was no consistently significant difference across the media over time. Finally, there is no consistently significant difference in perceived learning performance between two conditions; however, in general, students in FtFCL environment perceived the learning performance consistently better than their counterparts in CSCL groups.

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