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# Virtual Team Performance of Web-Mediated Communication Systems

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## Abstract

Web-mediated communication systems offer alternative ways of computer-aided communication within and across organizational contexts. Due to the high portability and functionality of such Web-mediated communication systems, more organizations are using this technology to support their group decision-making tasks. However, it is rare in literature for researchers to document the value of such Web-mediated communication systems. This study aims to investigate the virtual team performance of the Web-mediated communication systems among various contexts, and to study the performance systematically. First, a theory-based framework is proposed, and then an experiment is conducted. Results from the experiment show that Web-mediated communication technologies can be used as effectively as face-to-face meetings in terms of group decision making for various structural decision tasks. At the same time, the efficiency of Web-mediated communication systems increases the satisfaction of all participants.

*Keywords: Virtual Team, Decision Making, Web-mediated Communication Systems*

# 網際網路群體溝通系統之虛擬團隊績效

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## 摘要

網際網路群體溝通系統在組織內與組織間，提供不同的電腦輔助方式，以利團隊成員溝通。由於該系統的高度方便性與功能性，越來越多的企業組織，利用它來支援

群體決策制定的工作。然而，由於過去以網際網路為基礎的協同科技還在草創階段，文獻中少有記載此類系統應用的價值與效益。本研究旨在審視不同的情境下，網際網路群體溝通系統之虛擬團隊績效，並作有系統的分析。首先，我們提出一個以理論為基礎的研究架構，然後再在實驗室模擬各種不同的溝通模式，以觀察虛擬團隊成員間的互動與其團隊績效。從我們的實驗中，收集到的資料顯示，網際網路群體溝通系統可以和傳統面對面的會議，在解決結構化的決策問題時，能產生類似的效益。同時，使用此網際網路群體溝通系統，亦可增加虛擬團隊成員的滿意度。

*關鍵字：虛擬團隊、決策支援、協同科技、網際網路群體溝通系統*

## 1. Introduction

The integration of systems within and between organizations has led to the development of new organizational forms which are more flexible and responsive (Pasternack and Viscio, 1998; Jarvenpaa and Ives, 1994). Virtual teams consisting of individuals who are geographically and organizationally disbursed are increasingly common. As communication is often seen as the most important factor in coordinating work among team members (Doughery, 1992; Ancona and Caldwell, 1992; Pinto et al., 1993; Ebadi and Utterback, 1984), effective communication is vital for virtual teams that cannot meet in face-to-face settings. The use of technologies to support collaborative commerce continues to grow as accessibility increases and costs decline. But does the virtual team work effectively? Do the participants of the virtual teams communicate effectively? How will different communication modes influence the team performance? Will the use of collaboration technologies impact the team performance? The answers to the abov e questions need to be studied.

Many collaborative tools are emerging in the Internet environments to support teamwork (Warkentin et al. 1997; Ocker et al. 1998); however, most of these tools, such as online voting, discussion groups, chat rooms, desktop videoconferencing, are stand-alone tools. A salient feature of creative problem solving (CPS) is the process of CPS in addition to the use of assorted CPS techniques such as brainstorming (Torrence, 1974). Many Internet-based groupware tools lack direct support for the group process, limiting their effectiveness. In recent research on creativity (Wang et al., 2003), the results revealed that using a web-based group decision support system called TeamSpirit caused significant impact on individual

creativity and positively related to the increased amount of ideas generated. The findings of Wang et al. (2003) do not support the Media Richness Theory (Daft and Lengel, 1986), but support the Task-Media-Fit-Theory (McGrath and Hollingshead, 1993). This also encourages further research on collaborative technologies and virtual teamwork to investigate the comment that "more than 80 percent of about 200 studies have shown 'no difference' between specific collaborative technologies and face-to-face meetings," according to Fjermestad and Hiltz, 1998.

This study investigates the process and effectiveness of 14 randomly assigned virtual teams performing a decision-making task in an experimental setting. Each group uses the collaboration technology in different communication modes, except the control group which uses a traditional face-to-face environment. The analysis is designed to examine the differences in team/task performance carried out by groups using four communication styles in the experimental setting. This paper begins with a review of previous researches and various collaboration technologies, followed by the development of the research hypotheses, the research framework and research design, and research findings and discussions. Finally, the conclusion includes both the possible research constraints and potential research directions.

## 2. Literature Review

Much of the current research stems from the profound effect that technology has on group work (DeSanctis and Gallupe, 1987; Huber, 1984; Suh, 1999). Early research focused on the comparison between face-to-face meetings and meetings using various types of technological support. Most of these meetings are still in synchronous form. Rare related research was found on meetings conducted in an asynchronous setting. As stated by Pharmer (Pharmer, 2001), "the research on distributed teams is still in its infancy." Following are reviews of collaboration technologies, Web-based DSS, Web-based GDSS, and virtual teams, also known as distributed teams.

### 2.1 Collaboration Technologies

Collaboration was defined as activities that involve people engaged in various business processes (e.g., marketing, engineering, research and development) working together by sharing information and making decisions (Levitt and Mahowald, 2002). For example, to support better supply chain integration and customer services, it is important to involve not only

employees but also suppliers and customers in certain decision making processes. The group activities performed by teams while working together include: communicating ideas, exchanging and sharing information, coordinating activities, discussing issues, and making decisions. Collaboration technologies have evolved from various origins; therefore, people use various terms to describe these technologies, such as groupware (Johansen, 1988), inter-personal computing (Byte, 1990), group decision support systems (GDSS) (DeSanctis et al., 1987; Huber, 1984), computer-supported cooperative work (CSCW) (Greif, 1988), computer-mediated communication systems (CMCS), and team technologies (Alavi and Keen, 1989). Each term has a specific focus; for example, GDSS has a strong decision making orientation. The communication and coordination activities of team members are facilitated by technologies that can be characterized along three continua of time, space, and level of group support.

Table 1 depicts a space/time grid that can be used to classify various collaboration technologies. Most collaboration technologies used to conduct related research are in the synchronous form, including face-to-face meetings, telephone calls, desktop conferencing, a Web-based chat room, and the Internet Relay Chat (IRC). The development of collaborative tools evolves from "synchronous" to "asynchronous" and from "face-to-face" to "distance." Asynchronous meetings are more structured than synchronous meetings and are frequently used by groups in which at least one participant is in a remote location (Kinney and Panko, 1996).

Computer conferencing, which is a "structured form of electronic mail in which messages are organized by topic and dialogues are often mediated," can be asynchronous (such as bulletin board systems and Internet Usenet newsgroups) or synchronous (such as chat room and the IRC). Examples are EIES2 (Ocker et al., 1998) and MeetingWeb (Warkentin et al., 1997). The technology explored in this study, TeamSpirit, is a Web-based Group Decision-

▼ Table 1 Classification of Collaborative Technologies by Time and Place

| | Same Time (Synchronous) | Different Time (Asynchronous) |
|---|---|---|
| Same Place (Face-to-Face) | Multimedia presentation systems<br>Keypad-based voting systems<br>Facilitated meeting using a PC<br>LAN-based GDSS | Project/team rooms<br>Shared rooms |
| Different Place (Distance) | Screen sharing, Phone<br>Audio/Video conferencing<br>Web-based desktop conferencing<br>Instant Messaging, IRC, Chat room | Email, Discussion forum<br>Shared document databases<br>Group authoring tools<br>Web-based GDSS |

Making and Problem-Solving System which can support both synchronous and asynchronous meetings and is characterized by its process-oriented features and user friendly interface (Wang et al., 2003; 2004).

### 2.2 Web-based DSS

A Web-based Decision Support System (DSS) is a DSS built with Web technologies so that the DSS users access it with Web browsers via an Internet connection (Bhargava and Power, 2001; Power and Kaparthi, 2002). Web-based DSS users can be managers, business analysts, and trading partners who may use the DSS to retrieve decision related information or interact with decision models to analyze business data. Web-based DSS applications developed by companies may be deployed on corporate intranets to support internal business processes or they can be integrated into public corporate Web sites to enhance services to trading partners (Power and Kaparthi, 2002). These applications are very application-specific and support the more structured tasks of certain business processes. Web-based GDSS products, on the other hand, provide a more generic approach to solving complex problems that are less structured.

### 2.3 Web-based GDSS

Many first generation GDSS products, such as GroupSystems, are client/server-based and only support group decision making over local area networks. The Web is a natural medium that supports collaboration, decision making, and communication among distributed teams. However, few Web-based GDSS products are available due to the difficulty in building user-friendly Web-based applications. One of the first-generation Web-based GDSS systems called TCBWorks was initially developed by Alan Dennis et al. while at the University of Georgia in the mid-1990s (Dennis et al., 1996). TCBWorks was designed to allow team members to interact, discuss issues, and make decisions, and it is the first-generation technology for building Web-based applications. It combined structured discussion and multicriteria decision making into one tool, but did not explicitly support group decision-making processes.

GroupSystems is a LAN-based client/server application for online collaboration (GroupSystems.com, 2004). An add-on product called GroupIntelligence is a Web reporting tool for GroupSystems products. Therefore, GroupSystems has been used exclusively in face-to-face decision room environments with networks of PCs running Windows. After many years in the making, a new Web-based GDSS product from Ventana called Cognito was de-

veloped and released in the fourth quarter of 2003. The Cognito platform comprises three components: Cognito Task Server, Cognito Portal, and Cognito End User Client. Cognito chooses to use a client application via HTTP/HTTPS protocols providing more flexible drag-and-drop for moving or copying information items (Briggs, 2003). However, this type of implementation may cause configuration management complexity related to software upgrades. This is why many Web-based DSS/GDSS systems use only Web browsers on the client side.

There are several commercially available Web-based GDSS products that contain decision making tools. For example, Facilitate.com 8.0 provides support to the group decision making process with tools such as Brainstorming, Categorizing, Voting, Action Planning, Surveying, and Online Chat Rooms (Facilitator.Com, 2004). It comes with its own server. WebIQ is a similar Web-based system (WebIQ, 2003). It has an option that allows users to participate via email, and it also uses email to send out reminders to participants. WebIQ does not have a tool to support multicriteria decision making yet. There is only a simple tool to transfer ideas from one activity to another.

We are facing the challenges of supporting distributed teams because it is difficult for such teams to arrange face-to-face meetings or to meet at the same time virtually. Collaborative tools need to support both synchronous and asynchronous modes of communication. Therefore, Web technologies are used to build these tools rather than using client/server technologies. We believe that imposing appropriate structures on the processes and information content for asynchronous group activities is a critical factor in their effectiveness. Based on previous research in GDSS and CPS (Creative Problem Solving) (Liou and Chen, 1993; Wang and Horng, 2002; Warkentin et al., 1997), TeamSpirit is employed as a Web-based group decision making and problem-solving support system for distributed teams. There is a more detailed discussion of TeamSpirit in Section 4.3.

### 2.4 Virtual Teams / Distributed Teams

Virtual teams consist of cooperative relationships supported by information technology to overcome limitations of time and/or location (Morris et al., 2002). But do teams that collaborate online suffer from constraints in their ability to communicate? Can companies that implement virtual teams produce the same effect they would achieve if they assigned workers to collaborate on group tasks in the traditional way? The findings in recent years are not encouraging. For example, it was found that virtual teams exchange information less effectively than face-to-face groups (Hightower and Sayeed, 1995; 1996). However, if virtual

teams are given sufficient time to develop strong intra-group relationships and to adapt to the communication medium, they may communicate as effectively as face-to-face groups (Chidambaram, 1996).

Existing electronic technologies frequently used in the study of team-related research include phone, email, fax, videoconference, BBS, and WWW. Several studies compared various communication channels and concluded the following. Email is the most attractive and popular way to communicate, but it requires significant maintenance work. Phone is a more personal means of communication, but harder for speakers of other languages. Videoconferences may work better than a conference call for large groups. Face-to-face makes an effective communication channel that builds trust and confidence. Fax is more like a phone, but with a comparatively complicated operational process and hardware access. BBS is easy to use but only provides one-way communication (Groose, 2002). A chat room only works synchronously and functions as a loosely controlled form of a "meeting" without facilitation support. In team-related research, chat room is rarely used as one of the communication channels to support virtual teamwork. Videoconferences, on the other hand, are more frequently employed as the communication media in related research. Past research showed that VC teams (Videoconference) perform better than or as effectively as face-to-face (FtF) teams in terms of satsifaction (Valacich et al., 1994; Suh, 1999) in a synchronous meeting environment. The performance of VC and FtF teams in terms of decision quality varied for different tasks assigned in the work of Valacich, et al. (1994) and Suh (1999).

But as stated above, most collaboration technologies used in research are synchronous rather than asynchronous. Additionally, most past research using synchronous technology did not have significant influence on group work, whereas asynchronous technologies, including email and discussion forums, are probably more commonly seen in the business world than synchronous technologies (Kinney and Panko, 1996). Also, one pilot study using asynchronous technology conducted by Wang et al. (2003) reveals that collaboration technology will positively impact group work by measuring creativity as the team performance. Results show that, using IT to make teamwork outputs as organizational repository and provide real-time feedback stimulates participants to continue their work in a limited or assigned time period. These findings stimulate and encourage further research to examine if the same collaborative technology will make a significant difference in team performance on intellectual or decision making tasks.

In this study, the performance of teams using a Web-mediated communication system supporting both synchronous and asynchronous meetings is compared to the performance of

teams having face-to-face meetings. All teams are engaged in a specific decision making task. The primary research question is how teams using collaborative technologies in various communication modes work toward their team performance. The next section provides our research framework, followed by research design, research findings, and conclusions.

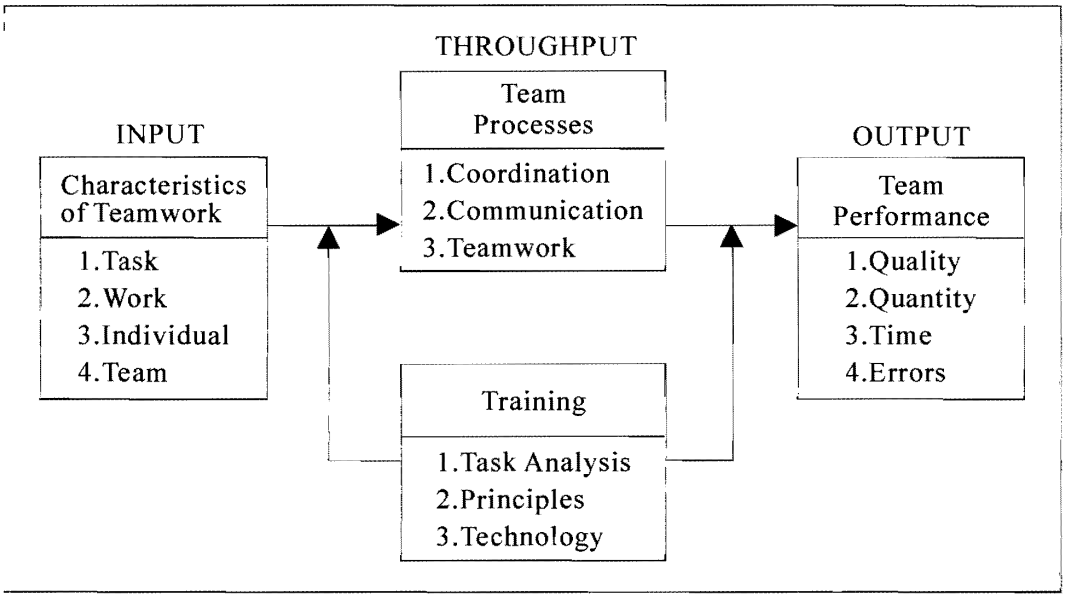
## 3. Research Framework

Evolving from the study of Ocker et al. (1998) on communication modes and team effectiveness and the study of Warkentin et al. (1997) on asynchronous technologies and team relational links, this study investigates the relationship among communication modes, team interaction, and team performance. The following sections start with a simplified team effectiveness model, followed by the research framework and several sets of hypotheses.

### 3.1 Team Effectiveness Model

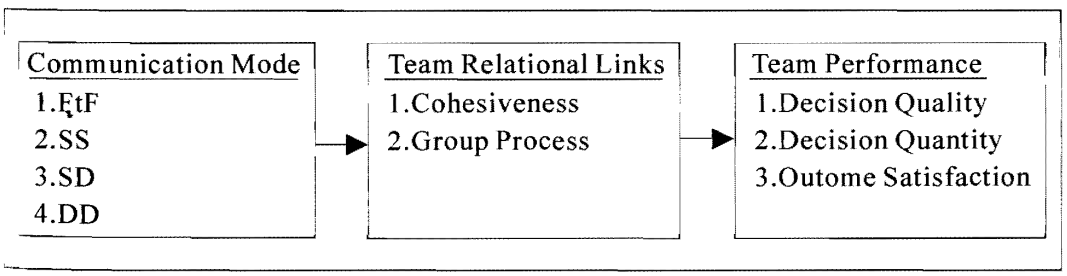
A team effectiveness model (TEM) is proposed by researchers to illustrate the interrelationships between input variables (characteristics of the team, the work, individual team member, and the task), throughput (team processes: coordination, communication, and teamwork activities; training: task analysis, principle, and technology) and team performance output (Salas et al., 1992). Figure 1 is a simplified Team Effectiveness Model which originated from the more comprehensive model by Salas et al. (1992). It is a common thread in team research literature that the relationship between the characteristics of a team and the performance of the team is mediated by a number of intervening variables. These variables affect the process by which team members coordinate activities and communicate with one another and, as a result, influence team performance. As the model suggests, the link between characteristics of the team and its performance is, in large part, attenuated by the impact of these characteristics on the team process variables of communication, coordination, and teamwork (Pharmer, 2001).

There are three subitems in the category of "Task" as one of the characteriestics of teamwork: task complexity, task organization, and task type. Work structure, team norms, communication, and structure are the four subitems in the category of "Work," another characteristic of teamwork. For the "Individual," factors to consider include motivation, attitudes, and gender/age. For the "Team," power distribution, homogeneity, and cohesiveness are three subitems to consider.




▲ Figure 1 Simplified Team Effectiveness Model (Adapted from Salas et al., 1992)

In a larger context, the three major parts of the model (input, throughput, and output) are controlled or affected by the organizational and situational characteristics which include reward systems, environmental uncertainty, supervisory control, and available resources. Our research framework is based on this TEM and focuses on the relationship between communication in the team process and team performance. More research can also be developed based on this model and past research results can impose their findings on the formation of our research model.




▲ Figure 2 Research Framework

### 3.2 Research Framework

Taking the team effectiveness model as a basis, and building on past research findings concerning the relationship between the communication mode and team performance, and

asynchronous technologies and team relational links (Warkentin et al., 1997; Ocker et al., 1998), this study condenses our research model as Figure 2. We focus on the link between " throughput" and "output" shown in the simplified TEM and consider those "input" characteristics (task, work, individual, and team) as controlled variables. In the communication modes, we elaborate the work of Ocker et al. (1998) to cover a more sophisticated essence of asynchronous communication. We use "FtF" to represent "face-to-face" team; "SS" to represent the virtual teams meet at the same time and in the same place with collaborative tool; " SD" to represent virtual teams meet at the same time and in different places with collaborative tool; "DD" for virtual teams meet at different times and in different places with collaborative tool. Meetings held at different times and in the same place are eliminated since they are rarely seen in the real world. Only a few so-called project/shared rooms can be seen in business organizations where staffs and employees often come and go to provide their knowledge or insights for certain projects or programs. The relationship between the communication modes and the variables investigated are listed below in Table 2.

There is substantial evidence that virtual teams communicate less efficiently than face-to-face groups (McGrath and Hollingshead, 1993; Hightower and Sayeed, 1995 and 1997). Because exchanging information is more difficult, virtual teams tend to be more task-oriented and exchange less social-emotional information, slowing the development of relational links (Chidambaram, 1996). Development of relational links is important because researchers have associated strong relational links with many positive outcomes, including enhanced creativity and motivation, and better decisions (Walther and Burgoon, 1992). The factors influencing relational links among team members are perceptions of group cohesiveness and perceptions of the group interaction process (Chidambaram, 1996).

Training, including both the technical usage of asynchronous technology and the domain knowledge of creative problem solving techniques, is considered to be a factor influen-

▼ Table 2 The Relationship between Communication Modes and Conditions Considered

| Types of Groups Compared | Condition Considered |
|---|---|
| FtF (with talking) vs. SS (with talking): Synchronous vs. Snychronous | Test the impact of using a tool |
| SS (with talking) vs. SD (without talking): Synchronous vs. Synchronous | Test the impact of location |
| SD (without talking) vs. DD (without talking): Synchronous vs. Asynchronous | Test the impact of time |

cing team performance. Yet in our study, we provide all experimental groups (except the control group) with basic training of using the Web-mediated communication system. Thus, "training" is neglected in our research framework. Team performance is operationalized by measuring the user's perception of decision quality, decision outcome satisfaction, and counting decision quantity (potential solutions).

### 3.2 Hypotheses

Media richness was defined as "the ability of information to change understanding within a time interval," (Daft and Lengel, 1986). Rich media allows multiple information cues (the words spoken, tone of voice, body language, etc.) and feedback. It takes more time and effort by group members to achieve the same level of mutual understanding in a lean medium, such as collaboration technologies, than in a rich one such as face-to-face communication. Comparatively speaking, FtF teams are considered to have communication channel with highest media richness; SS teams communicate through the media with "medium to high" media richnes; SD teams, on the other hand, use communication channel with "medium to low" media richness; and DD teams communicate with channel having the lowest media richness. Because collaboration tools reduce the amount and richness of the information that can be exchanged, it is more difficult for virtual teams to complete relationship-developing activities compared to face-to-face teams (W arkentin et al., 1997). Thus, the first set of hypotheses are:

H1a: FtF teams (talking and paper work) will exhibit stronger relational links than virtual teams (SS with talking).

H1b: Virtual teams (SS with talking) will exhibit stronger relational links than virtual teams (SD without talking).

H1c: Virtual teams (SD without talking) will exhibit stronger relational links than virtual teams (DD without talking).

In a study of team performance with 80 financial organizational groups, Campion et al. (1993) found that team process is positively related to their productivity, yet not positively related to outcome satisfaction. However, in another research of 60 knowledge groups (Campion et al., 1996), team process was found to be positively related to outcome satisfaction. Further research suggested that higher team cohesiveness, open communication, higher team member flexibility, and less conflicts between team members will result in higher team

performance. Potter and Balthazard (2002) also concluded that more agressive team interation will positively influence task performance. Thus, our second set of hypotheses are:

H2a: Teams with stronger relational links will generate a higher number of potential solutions (decision quantity).

H2b: Teams with stronger relational links will generate decisions with higher quality (decision quality).

H2c: Teams with stronger relational links will be more satisfied with their outcome (outcome satisfaction).

The study on face-to-face and virtual teams by Potter and Balthazard (2002) suggested that different team communication media will positively affect the team performance without mediation effect, whereas when both communication media and team interaction are positively related to team performance, communication media will influence the team performance through the mediation effect of team interaction. Therefore, the last set of our hypotheses are:

H3a: Considering the team relational links, the communication mode will influence the decision quantity through team relational links.

H3b: Considering the team relational links, the communication mode will influence the decision quality through team relational links.

H3c: Considering the team relational links, the communication mode will influence the outcome satisfaction through team relational links.

## 4. Research Design

This research used teams comprised of 3 or 4 members to complete a decision making task to conduct a relatively small-scale study. Teams used either synchronous or asynchronous communications to carry out their tasks. The following sections describe the task, the subjects, the collaborative tools, the research procedure, and the research instrument.

### 4.1 Task and Subjects

According to McGrath and Hollingshead (1993), this study chooses a decision making task for the subjects to complete. The subjects need to make a decision after exchanging in-

formation in a certain amount of time. The task was structured and decomposed into three stages: first, background information is given and can be accessed on the system; second, teams need to generate as many potential solutions as possible in a given amount of time; third, the evaluation tool provided by the system is used to generate the priority list of possible decisions. Before teams start to carry out their assignment, they were given basic training in the Web-mediated communication system and brief instructions to complete their task. Previous system preparation work needs to be done before the experiment begins.

The subjects are students from one university. They are senior undergraduate students with a background of management in business school and basic computer skills in working with Web-based applications. There are 54 subjects in total, which we formed into 14 groups in our experiment. Four of these 14 groups were placed in each of these three experimental groups: SS experimental group 1 (same time/same place/using tool/talking allowed), SD experimental group 2 (same time/different place/using tool/no talk), and DD experimental group 3 (different time/different place/using tool/no talk), respectively. The two groups left formed the control groups with a traditional face-to-face meeting environment.

### 4.2 Procedures and Instrument

Table 3 depicts a general description of the experimental procedure. It indicates that preparation work needs to be done before the experiment begins. Ad hoc conditions must also be considered in the design of the experiment. TeamSpirit is the Web-mediated communication system that we used to conduct our study. More detailed information about its functions and profound design logic is provided in the next section. In activity 4 of the experiment, each experimental group conducted different steps to complete their task within 30 minutes. The control groups were located in separate places to hold a traditional face-to-face meeting. Teams of SS experimental group 1 were located in the same computer lab and performed their assigned task. Teams of SD experimental group 2 were located in different computer labs to carry out their task. And finally, each team of DD experimental group 3 was divided into two subgroups to simulate the meeting settings at different time and in different places. All groups wer e allowed one additional day to modify their meeting outputs.

The instrument used in this research was adapted from those used by Wakentin et al. (1997) and Tjosvold (1988a; 1988b), and then modified after consulting with several scholars and experts. Three sets of variables were measured using the post-experiment instrument: Measures of Relational Links, Group Performance Measures, and User WWW Use variables. Two relational link variables were measured: Group Cohesiveness and Percep-

▼ Table 3 Experimental Procedures

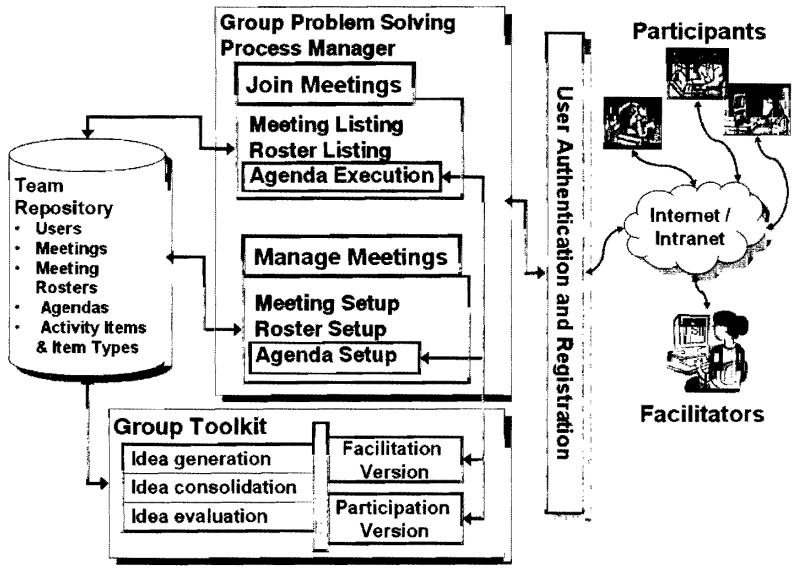
| Time / Steps | Contents | Remarks |
|---|---|---|
| Two weeks before experiment | 1. Select appropriate question<br>2. Set up TeamSpirit meeting | |
| One week before experiment | 1. Get the list of subjects, randomly assign groups<br>2. Prepare questionnaire | |
| Experiment starts | | |
| Activity 1: | Introduction | 10 min |
| Activity 2: | Basic Training of TeamSpirit (1) | 15 min |
| Activity 3: | Hands-on Practice of TeamSpirit (2) | 25 min |
| Rest | | 10 min |
| Activity 4: | Carry out task (control group and each experimental group with different steps, but totally consume 30 min) | 35 min |
| Activity 5: | Questionnaire | 15 min |

tions of Group Interaction Process. Group-related data were collected through the questionnaire on either a 5-point or 7-point Likert scale.

Data were also collected through the Web-mediated communication system, including the number of potential solutions (decision quantity), perception of decision quality, and outcome satisfaction. The instrument used for the face-to-face teams (control) group was nearly the same.

### 4.3 Web-Mediated Communication Systems: TeamSpirit

The World Wide Web has become an important medium for supporting the collaboration of distributed/virtual teams. Many products that support group collaborations are focusing on increasing the degree of presence among distributed team members by using Web-based audio or video conferencing tools. Some Web-based products, such as eRoom, focus on supporting project teams' document sharing. Support for group communications in existing Web-based collaboration technologies is limited to discussion forum, email, or instant messaging. TeamSpirit is a Web-based GDSS designed to support group problem solving and decision making with generic problem solving tools to be used by teams working anytime and anywhere. It is designed to facilitate any team member to create their own online meetings supporting group problem solving processes so that professionally trained facilitators are not required as they are in traditional meetings.




▲ Figure 3 The Architcture of TeamSpirit

The design of this Web-mediated communication system, called TeamSpirit, has been guided by CPS theories (Parnes, 1987), prior GDSS research and development (Dennis et al., 1988; Dennis et al., 1996; DeSanctis and Gallupe, 1987; Fjermestad and Hiltz, 1998), and collaboration technologies in the marketplace. The emergence of virtual teams in the global outsourcing environment and omnipresence of Internet and Web infrastructures are driving the development of Web-based GDSS (Vogel et al., 2001; Warkentin et al., 1997). TeamSpirit's architecture design closely followed the CPS processes and tools commonly used in general problem solving and decision making functionalities developed over time. So far TeamSpirit has been used for more than 100 online meetings with between 3 and 40 meeting participants, often working concurrently. Several empirical studies were conducted to validate system usefulness (Wang et al., 2003; 2004). These studies provided valuable feedback in improving system functionality and user interface design. Figure 3 depicts the TeamSpirit architecture.

An online "meeting" metaphorically represents a group problem solving process for a specific problem. A meeting consists of a roster and agenda. A roster contains a list of users who are invited by the facilitator to participate in the meeting. Every registered user can be a facilitator to create meetings. The facilitator can assign the facilitator's role to other users although it is not recommended that more than one facilitator is facilitating the same meeting at the same time. A meeting agenda consists of a list of agenda items representing

group activities. Each group activity is supported by one of the group tools built into TeamSpirit. The agenda in TeamSpirit is not static, but is an executable agenda meeting participants can use to invoke the appropriate participation version of a group tool. The facilitator needs to design a group decision making or problem solving process according to the problem or issue at hand and set up a meeting agenda accordingly.

TeamSpirit is designed to support the Creative Problem Solving (CPS) processes. It classifies meeting users into two different roles: participants and facilitators. Any user can create a new meeting and become a facilitator of a meeting. A facilitator of a meeting can invite existing users who are registered with a TeamSpirit site to join a meeting as participants. A facilitator can also change the role of a user from a participant to a facilitator. If a meeting has more than one facilitator, they must coordinate their efforts so that they do not try to set up a meeting activity at the same time. While one TeamSpirit design objective is that any user can facilitate meetings, the skills required to be an effective facilitator take time to develop. The major components of the TeamSpirit architecture are the following:

(1)User authentication and registration function

Check a user's username and password to determine the meetings in which the user can participate or facilitate. Users must log in first in order to use the system. Users who try to access other functions without logging in will be detected and forwarded to the login program. New users can register themselves online, or can be registered by a meeting facilitator.

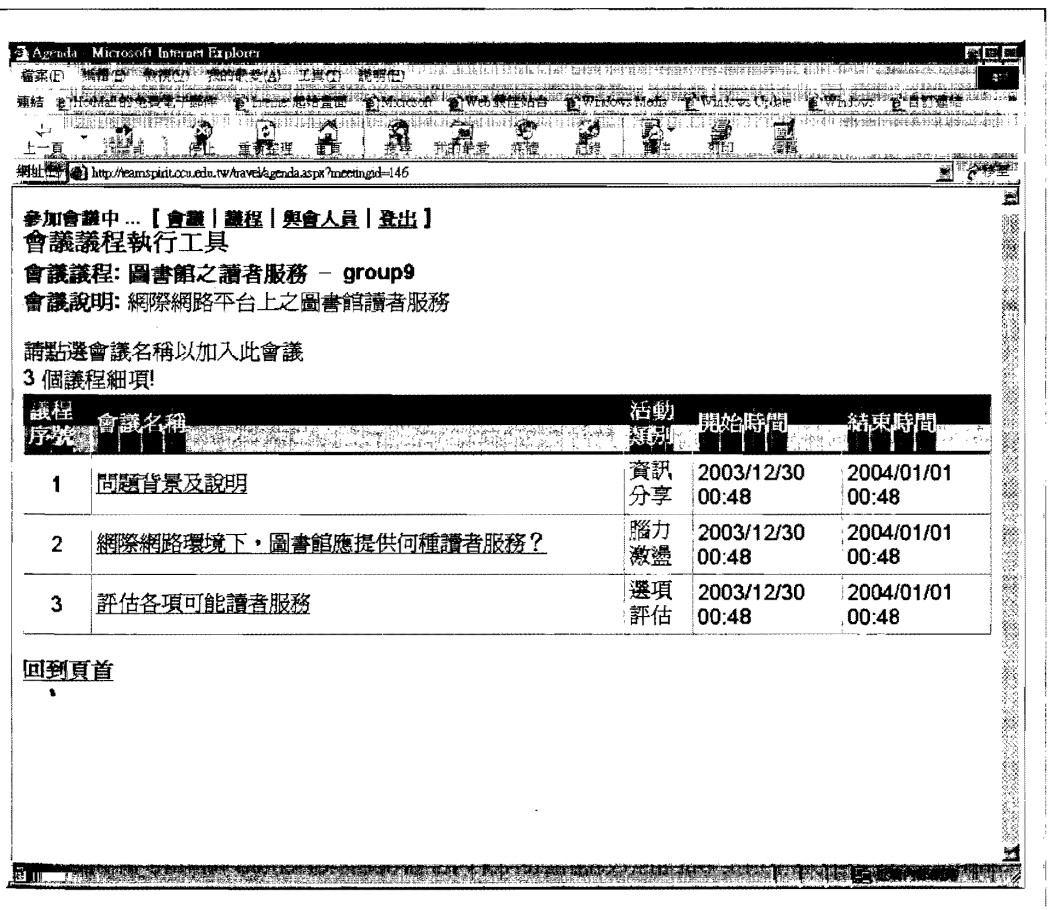
(2)A group problem solving process manager

This subsystem has two major functions: (a) Join meetings function: This is used by meeting participants to view a list of meetings in which they are invited to participate. From the *meeting listing*, the user can choose a link to a meeting to view the meeting agenda or *roster* (a list of meeting participants). From the meeting agenda, a list of agenda items is displayed indicating the activity type, and the starting and ending time of each agenda item which is linked to a group tool to support certain types of group activities. By clicking on an agenda item, the participant invokes the *agenda execution* program to invoke the participant version of a group tool that supports a group activity. (b) Manage meetings function: A facilitator can use this function to set up a meeting. Meeting setup involves the following tasks: (1) Create a meeting agenda which consists of a list of group activiti es, each of which is supported by a group tool; (2) Each agenda item representing an activity and supported by a group tool may need additional setup such as maximum value of a rating activity; (3)

Invite existing users or create new users to participate in the meeting and send email to inform participants they have been invited to join the meeting. An additional email message should be sent out to remind people to join an activity when it becomes active. An example of a meeting agenda is shown in Figure 5. The sequence of the agenda items is determined by the beginning time of each activity in the agenda.

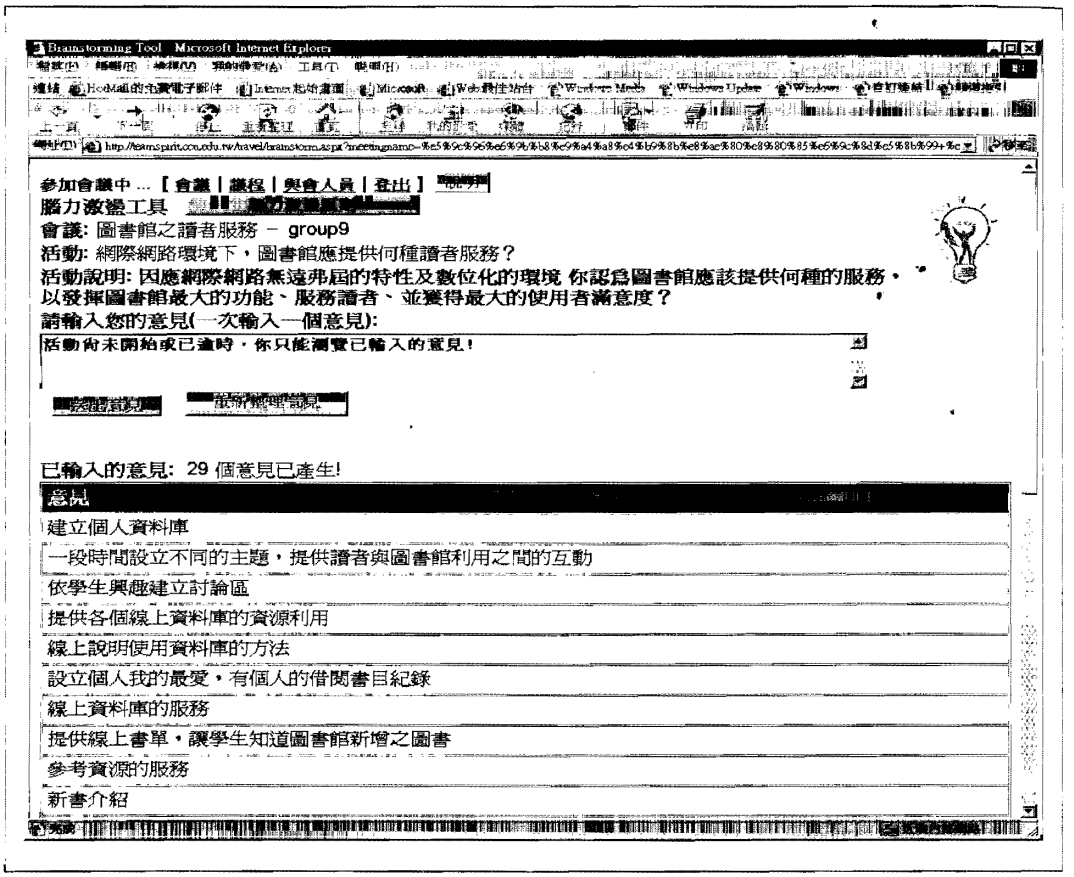
(3)Group toolkit

A set of tools has been developed to support different types of group activities. These tools are classified into three major categories: idea generation, idea consolidation, and idea evaluation tools. This classification is consistent with the general creative problem solving process. Each group tool has two versions (i.e., programs): (a) a participation version that is used by a meeting participant when he or she is engaged




| 議程序號 | 會議名稱 | 活動類別 | 開始時間 | 結束時間 |
|---|---|---|---|---|
| 1 | 問題背景及說明 | 資訊分享 | 2003/12/30 00:48 | 2004/01/01 00:48 |
| 2 | 網際網路環境下，圖書館應提供何種讀者服務？ | 腦力激盪 | 2003/12/30 00:48 | 2004/01/01 00:48 |
| 3 | 評估各項可能讀者服務 | 選項評估 | 2003/12/30 00:48 | 2004/01/01 00:48 |

▲ Figure 4 Sample TeamSpirit Meeting



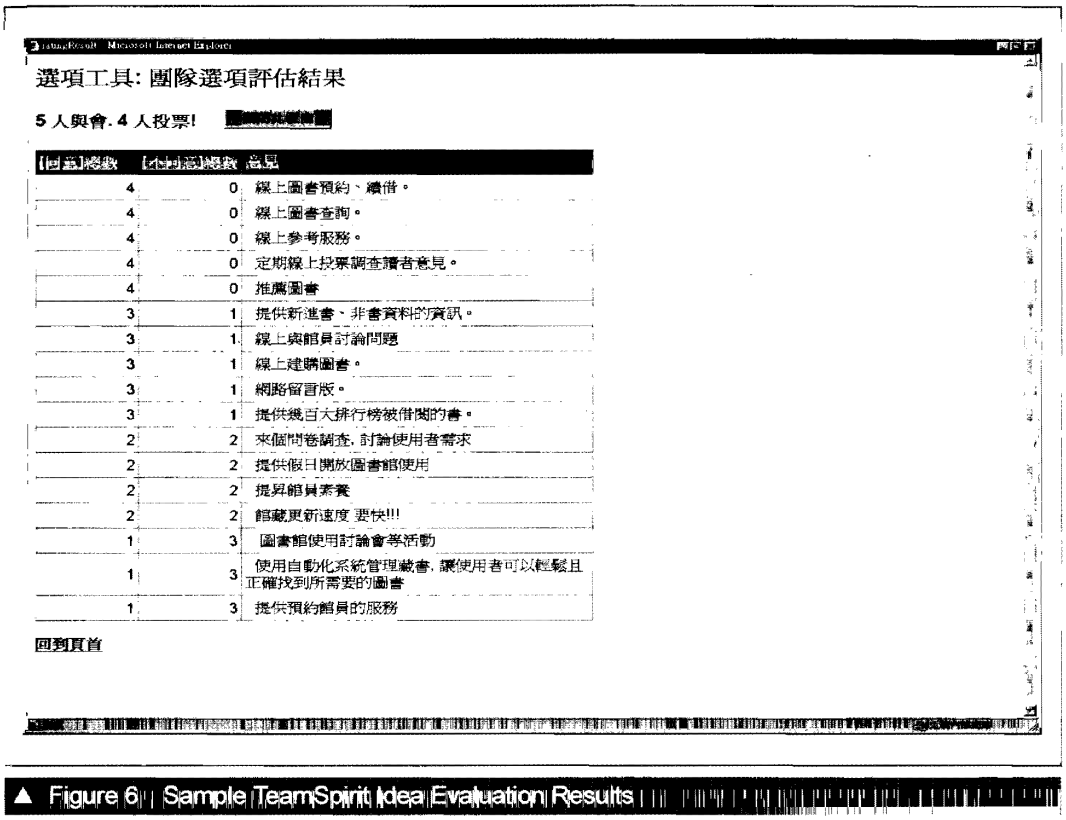

▲ Figure 5 Sample TeamSpirit Idea-Generation Results

in a meeting activity supported by the tool; (b) a facilitation version (i.e., setup tool) that is used by a meeting facilitator to set up parameters or data items associated with a meeting activity. One major effort by a facilitator during a meeting is to organize ideas generated from the idea generation activities so that a list of consolidated alternatives can be used for the evaluation activities that follow.

(4)Meeting repository

A relational database is used to implement the meeting repository storing all the meeting related information including meeting setup information as well as ideas generated and evaluated by various group tools.

Different from most computer conferencing systems, TeamSpirit not only supports an electronic meeting platform, but also characterizes its process-oriented feature in integrating meeting activities as a whole. It was developed with detailed knowledge of group support systems and the three steps of creative problem solving, i.e., idea generation, idea consolida-



選項工具: 團隊選項評估結果

5 人與會. 4 人投票!

| [同意]總數 | [不同意]總數 | 意見 |
|---|---|---|
| 4 | 0 | 線上圖書預約、續借。 |
| 4 | 0 | 線上圖書查詢。 |
| 4 | 0 | 線上參考服務。 |
| 4 | 0 | 定期線上投票調查讀者意見。 |
| 4 | 0 | 推薦圖書 |
| 3 | 1 | 提供新進書、非書資料的資訊。 |
| 3 | 1 | 線上與館員討論問題 |
| 3 | 1 | 線上建購圖書。 |
| 3 | 1 | 網路留言版。 |
| 3 | 1 | 提供幾百大排行榜被借閱的書。 |
| 2 | 2 | 來個問卷調查, 討論使用者需求 |
| 2 | 2 | 提供假日開放圖書館使用 |
| 2 | 2 | 提昇館員素養 |
| 2 | 2 | 館藏更新速度 要快!!! |
| 1 | 3 | 圖書館使用討論會等活動 |
| 1 | 3 | 使用自動化系統管理藏書, 讓使用者可以輕鬆且正確找到所需要的圖書 |
| 1 | 3 | 提供預約館員的服務 |

回到頁首

▲ Figure 6 Sample TeamSpirit Idea Evaluation Results

tion, and idea evaluation. TeamSpirit formulates its meeting tools as sharing information, brainstorming, multi-aspect brainstorming, and discussion forum to form the idea generation phase; functions for rating, ranking, yes/no, and multi-criteria decision making constitute the idea evaluation phase; and the idea consolidation tool is used to connect the two phases. Figures 4, 5, and 6 depict one group's meeting and the resulting idea generation and idea evaluation phases of TeamSpirit during their performance of the team task. These figures are in Chinese to serve those students whose native language is Chinese and to prevent any barrier from language. The figures also indicate that teams work in a Web-based environment and the decision making task was decomposed into two stages -- the idea generation phase to generate as many potential solutions as possible, and then the idea evaluation phase to generate a priority list of potential solutions. An idea consolidation tool was used to connect these two phases and make the decision making process an integrated one.

## 5. Research Findings

This research studied the relationships among different communication modes, team relational links, and team performance. In our experimental design, we divided students into four groups (each with four subgroups of 3 to 4 team members.) Teams of SS experimental group 1 were in the same time/same place/using tool/talking-allowed meeting settings (abbreviated as SS); teams of SD experimental group 2 were in the same time/different place/using tool/no-talk meeting environment (abbreviated as SD); and teams of DD experimental group 3 were in the different time/different place/using tool/no-talk meeting background (abbreviated as DD), respectively. The remaining two groups formed the control groups with a traditional face-to-face meeting environment. The following data analysis compares the differences among groups to investigate how the team relational links and team performance (decision quantity, decision quality, and outcome satisfaction) were affected and further, to understand the relationships among t hese three constructs. The followings sections include basic statistics of experimental subjects, descriptive statistics of different variables, hypothesis examination, regression analysis for mediation effect, and result explanation.

### 5.1 Basic Statistics of Subjects

Table 4 illustrates the basic statistics of experimental subjects. There were 54 subjects in total in 14 groups who participated in our experiments, with 23 male (42.6%) and 31 female students (57.4%). In each experimental group, there are 4 subgroups with 3 (14.29%) - 4 (85.71%) team members. Two groups formed control groups (13%), each with 3 and 4 team members. 98.1% of subjects had basic WWW skills to some extent and 96.3% of them work (or play) with the Internet to a certain degree.

Since the characteristics of the "individual" subject do not constitute our research framework, we consider the gender, WWW skills, and WWW frequency of subjects as controlled variables. TeamSpirit is furnished with a friendly user interface and is quite easy to use (as can be seen from the subjects' feedback about the collaborative tool collected after the experiments). In addition, since basic training was provided before the experiment started, all of these should minimize the effect of the individual characteristics on team performance. Yet, larger-scale research in virtual teamwork in business organizations in the real world are considered to be our further study to explore the relationships of various variables in the Team Effectiveness Model (TEM). This study with student as subjects can be seen as pre-

liminary work toward better understanding of virtual teamwork with TeamSpirit.

▼ Table 4 | Data Analysis of Experimental Subjects

| Item | | Sample Size | Percentage (%) |
|---|---|---|---|
| Gender | Male | 23 | 42.6% |
| | Female | 31 | 57.4% |
| Size of Experimental Group | Experimental Group 1 | 16 | 29.6% |
| | Experimental Group 2 | 15 | 27.8% |
| | Experimental Group 3 | 16 | 29.6% |
| | Control Group 4 | 7 | 13% |
| Size of Group | 4 members | 12 | 85.71% |
| | 3 members | 2 | 14.29% |
| WWW Skill | No experience | 1 | 1.9% |
| | Low | 41 | 75.9% |
| | Medium | 9 | 16.7% |
| | High | 3 | 5.6% |
| WWW Frequency | Seldom | 2 | 3.7% |
| | Sometime | 5 | 9.3% |
| | Regular | 5 | 9.3% |
| | Frequent | 42 | 77.8% |

### 5.2 Statistical Results of Research Construct

The mean and standard deviation of each construct measured in this research are listed in Table 5 for the team relational links and team performance, and Table 6 for the decision quantity (number of potential solutions) and decision quality (perceptions of decision quality). As for the team relational links, we found that team members meeting in a face-to-face environment outperformed the other three virtual teams (FtF > = SS > SD > DD). Yet, SS experimental group 1 (same time/same place/using tool/with talking) generated similar results to those of FtF control group.

For the construct of team performance, we found almost similar means for all four experimental groups (FtF > = DD > DD > SD). However, the means of both DD experimental group 3 and the FtF control group are almost the same, which slightly differentiate

▼ Table 5 Mean and Standard Deviation of Dependent Variables (1)

| Dependent \ Independent Var. | | SS / Experiment 1 | SD / Experiment 2 | DD / Experiment 3 | FtF / Control Group |
|---|---|---|---|---|---|
| Team Relation -al links | Mean | 5.39 | 5.13 | 5.03 | 5.46 |
| | SD | 0.947 | 0.778 | 0.946 | 0.488 |
| Team Performance | Mean | 5.84 | 5.81 | 5.98 | 5.99 |
| | SD | 0.822 | 0.898 | 0.928 | 0.535 |

▼ Table 6 Mean and Standard Deviation of Dependent Variables (2)

| Dependent \ Independent Var. | | SS / Experiment 1 | SD / Experiment 2 | DD / Experiment 3 | FtF / Control Group |
|---|---|---|---|---|---|
| Decision Quantity | Mean | 20 | 13.75 | 17.5 | 18.5 |
| | SD | 4.967 | 7.5 | 6.758 | 3.536 |
| Decision Quality | Mean | 6.25 | 4.75 | 5.25 | 5 |
| | SD | 0.957 | 1.5 | 2.062 | 0.00 |

them from the SS and SD experimental groups (1 and 2).

From Table 6, we can find that virtual teams can generate as many potential solutions (decision quantity) as traditional face-to-face teams (SS > FtF > = DD > SD). Yet the decision quality (evaluated by specialists) of SS experimental group 1 (same time/same place/use tool/talking) and DD experimental group 3 outperformed the other two groups (SS > DD > FtF > SD). Also, DD virtual teams (different time/different place/use tools/no talk) generated slightly better task results.

### 5.3 Hypotheses Testing

#### 5.3.1 Influence of Communication Mode on Team Relational Links

▼ Table 7 Results of ANOVA for Hypothesis 1

| Variable | F(df = 3,14) | p-value |
|---|---|---|
| Cohesiveness | 5.115 | 0.035 |
| Perceptions of Group Interaction Process | 4.098 | 0.011 |

H1 proposes that face-to-face groups will have stronger relational links than virtual teams. Data analysis supported this hypothesis. Table 7 shows the results of ANOVA per-

formed for each of the variables of team relational links. Cohesion and perceptions of group interaction process are all significant on a 0.05 significant level. The means for the two variables of team relational link are shown in Table 8. Face-to-face groups (control group) reported a higher degree of cohesion, were more satisfied with the decision process followed by the groups, and were more satisfied with the team's outcome.

Table 8 Means of Relational Variables

| Dependent Variable | SS(n = 4) | SD(n = 4) | DD(n = 4) | Face-to-Face(n = 2) |
|---|---|---|---|---|
| Cohesion | 7.9375 | 7.4667 | 7.25 | 8.5714 |
| Perceptions of Group Interaction Process | 10.5 | 10 | 10.875 | 12.5714 |

### 5.3.2 Influence of Team Relational Links on Team Performance

This set of hypotheses examines how team relational links affect team performance. We used the team relational links as the independent variables, and the decision quantity (number of potential solutions), decision quality, and perceptions of outcome satisfaction as dependent variables to conduct MANOVA analyses. Data analysis showed that team relation links will partially affect the team performance variables (see Table 9). Both decision quantity and outcome satisfaction were affected positively under a 0.05 significant level, whereas decision quality is not positively related to the team relational links on a 0.05 significant level.

Table 9 Results of MANOVA for Hypothesis 2

| Hypothesis | Independent Variable | Dependent Variable | F-value | p-value |
|---|---|---|---|---|
| H2a | Team | Decision Quantity | 3.854 | 0.038 |
| H2b | Relational | Decision Quality | 6.509 | 0.073 |
| H2c | Links | Outcome Satisfaction | 8.319 | 0.007 |

### 5.3.3 Influence of Communication Mode on Team Performance

This examines how communication styles affect team performance. We used the communication mode as the independent variable, and the decision quantity (number of potential solutions), decision quality, and perceptions of outcome satisfaction as dependent variables to conduct three ANOVA analyses. Data analysis showed that communication mode will significantly affect all the team performance variables, including decision quantity, decision

▼ Table 10 Results of ANOVA for Supplement Hypothesis 1

| Hypothesis | Independent Variable | Dependent Variable | F-value | p-value |
|---|---|---|---|---|
| Supplement to H1a | Supplement to H1a | Decision Quantity | 3.42 | 0.024 |
| Supplement to H1b | Mode | Decision Quality | 6.509 | 0.001 |
| Supplement to H1c | | Outcome Satisfaction | 3.44 | 0.024 |

▼ Table 11 Means of Team Performance Variables

| Dependent Variable | SS(n = 4) | SD(n = 4) | DD(n = 4) | Face-to-Face(n = 2) |
|---|---|---|---|---|
| Decision Quantity | 20 | 13.8 | 17.5 | 18.71 |
| Decision Quality | 6.25 | 4.47 | 6.00 | 5.0 |
| Satisfaction with Outcomes | 22.0625 | 19.4667 | 21.75 | 25.4286 |

quality, and outcome satisfaction under a 0.05 significant level (see Table 10). Table 11 shows that virtual teams could make better quality decisions than face-to-face groups (SS > DD > FtF > SD); yet within the virtual teams, those teams working at the same time and in the same place will have the highest team performance.

### 5.3.4 Regression Analysis of the Mediation Effect of Team Relational Links

According to the analytical procedure proposed by Baron and Kenny (1986), we carried out three regression analyses to examine the mediation effect of Team Relational Links. First (step 1), the mediator is significantly influenced by the independent variable. Second (step 2), the dependent variable is significantly influenced by the independent variable. Finally (step 3), the regression formula is established when there is the mediation variable included in the regression analysis and the dependent variable is significantly influenced by it. Tables 12 - 14 show the results of regression analyses of hypotheses 3. From the regression analysis results of Table 12, we found that the ability to explain the mediation effect of Team Relational Links on the relationship of communication mode and decision quantity was decreased from 1.5% to -0.2%, and it is not significant for the regression formula to establish (step 3) under a significant level 0.05. Thus, there is not enough evidence in our study to verify that there is mediation effect of team relational links on the relationship between communication mode and decision quantity. Data analysis did not support hypothesis H3a.

From the regression analysis results of Table 13, though the ability to explain the mediation effect of team relational links on the relationship between communication mode and

▼ Table 12 Regression Analysis of Mediation Effect on Decision Quantity

| Step | Dependent Variable | Independent Variable | Standardize Beta | t-value | p-value | Adj-$R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Step 1 | Team Relational Links | Communication Mode | -0.216 | -1.595 | 0.117 | 0.028 | 0.047 |
| Step 2 | Decision Quantity | Communication Mode | -1.043 | -1.336 | 0.187 | 0.015 | 0.033 |
| Step 3 | Decision Quantity | Communication Mode | -0.194 | -1.376 | 0.175 | -0.002 | 0.036 |
| | | Team Relational Links | -0.054 | -0.382 | 0.704 | | |

P.S.: + = P <.1; * = P <.05; ** = P <.01; *** = P < 0.001

▼ Table 13 Regression Analysis of Mediation Effect on Decision Quality

| Step | Dependent Variable | Independent Variable | Standardize Beta | t-value | p-value | Adj-$R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Step 1 | Team Relational Links | Communication Mode | -0.216 | -1.595 | 0.117 | 0.028 | 0.047 |
| Step 2 | Decision Quantity | Communication Mode | 0.041 | 0.299 | 0.776 | -0.017 | 0.002 |
| Step 3 | Decision Quantity | Communication Mode | 0.0094 | 0.674 | 0.503 | 0.021 | 0.058 |
| | | Team Relational Links | 0.242+ | 1.741 | 0.088 | | |

P.S.: + = P <.1; * = P <.05; ** = P <.01; *** = P < 0.001

decision quality was increased from -1.7% to 2.1% and the team relational links have slightly significant impact on the decision quality, yet the Beta-value (0.242) is larger than the Beta value (-0.216) generated in Step 1. Thus, there is no significant evidence in our study to verify that there is mediation effect of team relational links on the relationship between communication mode and decision quality. Data analysis did not support hypothesis H3b.

Table 14 reveals that the ability to explain the mediation effect of team relational links on the relationship between communication mode and outcome satisfaction was decreased from 3.9% to -0.2% and that team relational links are significantly related to outcome satisfaction, yet the Beta-value (0.703) is larger than the Beta value (-0.216) generated in Step 1. Thus, there is no significant evidence in our study to prove that there is a mediation effect of

team relational links on the relationship between communication mode and decision quality. Data analysis did not support hypothesis H3c.

Table 14 Regression Analysis of Mediation Effect on Outcome Satisfaction

| Step | Dependent Variable | Independent Variable | Standardize Beta | t-value | p-value | Adj-$R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| Step 1 | Team Relational Links | Communication Mode | -0.216 | -1.595 | 0.117 | 0.028 | 0.047 |
| Step 2 | Outcome Satisfaction | Communication Mode | -0.24 + | -1.78 | 0.084 | 0.039 | 0.057 |
| Step 3 | Outcome Satisfaction | Communication Mode | -0.088 | -0.893 | 0.376 | -0.002 | -0.036 |
| | | Team Relational Links | 0.703 *** | 7.132 | 0.000 | | |

P.S.: + = P <.1; * = P <.05; ** = P <.01; *** = P < 0.001

## 6. Discussions and Conclusions

This section summarizes the research findings and provides possible explanations for the research results. The first part concludes the results of hypothesis examination and descriptive statistics and other experimental results of ANOVA and MANOVA analysis. The second part will provide possible explanation of the research results. The last part discusses the research constraints and future research suggestions.

### 6.1 Research Findings and Discussions

Table 15 summarizes the results of descriptive statistics. We found that for team relational links, the FtF teams were superior to the other three virtual teams. But the performance of FtF teams on team relational links is only slightly better than that of SS teams. This indicates that the collaborative tool used for virtual teamwork can generate a similar effect on team relationship as the traditional FtF teams. Since talking or conversation was allowed for team members during meetings, this might be another contributing factor on the similar effect of FtF and SS teams on team relational links.

For team performance, FtF teams had the highest level of meeting output and were better than the other three virtual teams. Yet, the team performance of DD teams was slightly

▼ Table 15 Summary of Descriptive Statistics

| Description of Statistical Items | Results |
|---|---|
| Team Relational Links | FtF >= SS > SD > DD |
| Team Performance | FtF >= DD > SS > SD |
| Decision Quantity | SS > FtF >= DD > SD |
| Decision Quality | SS > DD > FtF > SD |
| Satisfaction with Outcomes | FtF > SS > DD > SD |

lower than that of the FtF teams, which indicates that virtual teams working at a different time and in a different place can perform almost the same as the FtF teams using the Web-based collaborative tool. This may be because DD team members can access the systems to complete their assigned task at any time, while the FtF teams can only work together for the task when they meet at the same time. Thus, this collaborative tool can serve as a communication channel for virtual teams of organizations that have at least one group member who cannot attend the meeting, thereby saving the cost of travel expenses.

The decision quantity is measured by counting the number of possible solutions created in the idea generation stage. SS teams outperformed the FtF and DD teams, which had an identical number of ideas. The SS team members can get excited when they meet at the same time for their task, and it can stimulate their productivity because they can browse the temporary meeting results at any time during the meeting. Thus, the number of potential solutions generated by SS teams is higher than that of traditional FtF teams where not every meeting participant will jot down the temporary meeting results.

The decision quality of virtual teams is evaluated and verified by domain specialists. We found that the decision quality of both SS and DD teams was better than that of FtF and SD teams. The media synchronicity may contribute to SS teams having the best results for decision quality, while the convenience for DD teams to work at different times and in different places may contribute to their satisfactory results. For outcome satisfaction, research results indicate that FtF teams are again superior to the other three teams. The concurrent discussion and feedback to each meeting participant while the meeting is occurring can help in the development of mutual understanding and cooperation in completing the assigned decision making task.

Table 21 is a summary of research hypothesis examination results. For the effect of communication mode on team relational links, we found that research results significantly support our hypotheses. For the effect of communication modes on team performance, we

▼ Table 16 Results of Research Hypothesis Examination

| Description of Research Hypotheses | Results |
|---|---|
| H1: The effect of communication modes on team relational links. | Y |
| H1a: FtF teams (talking and paper work) will exhibit stronger relational links than virtual teams (SS with talking). | Y |
| H1b: Virtual teams (SS with talking) will exhibit stronger relational links than virtual teams (SD without talking). | Y |
| H1c: Virtual teams (SD without talking) will exhibit stronger relational links than virtual teams (DD without talking). | Y |
| Supplement to H1: The effect of communication modes on team performance. | Y |
| Supplement to H1a: Communication modes on decision quantity. | Y |
| Supplement to H1b: Communication modes on decision quality. | Y |
| Supplement to H1c: Communication modes on outcome satisfaction. | Y |
| H2: The effect of relational links on team performance. | - |
| H2a: Teams with stronger relational links will generate a higher number of potential solutions (decision quantity). | Y |
| H2b: Teams with stronger relational links will generate decisions with higher quality (decision quality). | N |
| H2c: Teams with stronger relational links will be more satisfied with their outcome (outcome satisfaction). | Y |
| H3: Mediation effects of communication mode on team performance. | N |
| H3a: Considering team relational links, the communication mode will influence the decision quantity through team relational links. | N |
| H3b: Considering team relational links, the communication mode will influence the decision quality through team relational links. | N |
| H3c: Considering team relational links, the communication mode will influence the outcome satisfaction through team relational links. | N |

P.S. "Y" represents that the experimental results support the hypothesis.
"-" represents that the experimental results partially support the hypothesis.
"N" represents that the experimental results do not support the hypothesis.

found that research results support our hypotheses. For the effect of team relational links on team performance, we found that research results partially support our hypotheses. Research results did not support the H2b hypothesis which states that, "Teams with stronger relational links will generate decisions with higher quality." For the mediation effect of team relational links on the relationship of communication modes on team performance, research results do not support the hypotheses. We speculate that is a result of the relatively small size of our experiments. Thus, the data collected from our experiments is not sufficient for statistical analysis. Studies with more experimental subjects need be carried out to observe the effect of sampl e size on team performance.

### 6.2 Conclusions

Experiment results show that Web-mediated communication technologies could be used as effectively as face-to-face meetings in terms of group decision making for various structural decision making tasks. The efficiency of Web-mediated communication systems increased the satisfaction of all participants. In our study, the decision making task was decomposed into two steps, which provided the meeting participants opportunity to make decisions "structurally". Our study also found evidence that SS-virtual teams (meeting at the same time and in the same place with a collaboration tool) can perform better than the traditional face-to-face teams, because the Web-mediated communication system provided a platform for meeting participants that allowed them to focus on their assignment and enabled real-time feedback which stimulated their enthusiasm to respond quickly. DD-virtual teams (meeting at different times and in different places with a collaboration tool) could generate a similar amount of potential s olutions (decision quantity) as the face-to-face groups, yet they had a higher outcome satisfaction. We found that when teams were allowed more time to meet online at different times and in different places, they tended to have the motivation to recheck their task outputs. This could be observed from the Web-mediation communication system and explained the similar team performance output as the traditional face-to-face teams.

Though the collaboration tool provides a platform for online meetings if at least one participant cannot attend the meeting, the meeting task and meeting activities need to be well organized and formatted by an experienced meeting facilitator. During our experiment, we found that the meeting platform would sometimes become a chat room. This caused unexpected results and increased the difficulty of the data analysis stage. Thus, the management of virtual teams is important in our future study to eliminate any possible interference with the research results.

### 6.3 Research Constraints and Future Research Direction

This is an in-progress research to study how different communication modes of virtual teams affect team performance through team interaction in a Web-based environment. Three types of virtual teamwork were carried out in an experimental setting to complete a decision making task. The research findings and any shortcomings found during the experimental process will be recorded and modified for further large-scale study. The sample size is relatively small which may cause statistical errors or make it difficult to get meaningful statistical results. Since we used an experimental approach, external validation presents a problem. Also, since students were used as experimental subjects, the results are not appli-

cable to the real world. Many variables in the simplified team effectiveness model are controlled and neglected in our research framework. Thus, more explanation may be needed to describe research results and additional future research is needed to elaborate on the TEM model.

Business organizations and managers need teamwork, group decision making, and meetings to solve their problems and gain a competitive advantage in the ever-changing business environment in which they face multiple threats from the market and competitors. Managers in business organizations spend an average of 30 - 80 percent of their time in meetings, so they need to gain as much productivity as possible related to the expense in both time and cost. Past research showed that meeting effectiveness is so low (Mosvick and Nelson, 1987; Dennis et al., 1990) that managers are facing challenges to find new techniques to improve team performance. Therefore, they tend to be more serious and cautious and handle such problems with circumspection. Students, on the other hand, are likely to form a loosely controlled meeting to deal with their assignment, unless there is a corresponding reward system and benefits to interest them. This, again, can be illustrated by the "motivation" and "attitudes" of individual charac teristics of meeting participants in the TEM model and be considered one aspect for future research.

As for the future research direction and potential research topics, various combinations of variables in the TEM model can form a valuable research study. In the larger-scale experiment of our study, virtual teams will consist of participants from geographically dispersed locations. Other communication media can also be considered as variables to study their impact on team performance of virtual teams. Meanwhile, the Web-mediated collaboration tool, TeamSpirit, can also be applied to areas such as collaborative learning, new product development, research project collaboration, strategic planning, creative problem solving, project evaluation, policy formulation, conflict resolution/negotiation, focus group marketing research, joint information systems planning, requirements elicitation/design, knowledge elicitation, and decision making.

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