Sabbatical Report, Fall 2014

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Submitted to http://repository.library.csuci.edu/handle/10139/743

The Development of a Web-Based Creative Group Problem Solving System
to Support Online Learning and Virtual Teamwork

I. Summary of Purpose and Goals

The purpose of my sabbatical leave is the redesign and redevelopment of a Web-based creative group problem solving system called TeamSpirit. The prototype system was developed before I joined CI in 2008. It was built in an old Microsoft environment: ASP.NET 2.0, Visual Studio 2005, and Access database. These older technologies and the low-end database system have resulted in performance issues and the system in its current form is not appropriate for large-scale deployment. Although I have used the prototype system in my teaching and research for several years, the usage has been very limited and has resulted in less than desirable outcomes due to poor performance and the lack of more advanced features.

TeamSpirit's development was initially influenced by research in the group decision support system field. The system has built-in support for online meetings. An online meeting (i.e., an instance of a group process) is defined by a meeting agenda containing several agenda items. Each agenda item is associated with the use of a group tool to facilitate a group activity. Several group tools support group techniques for idea generation and evaluation such as brainstorming, voting, information sharing has been developed. Data generated in an activity can be used (via import and export) with other activities.

From the technical side, the Access database needs to be migrated to a more powerful database server such as Microsoft's SQL Server. The integrated development environment (IDE) also needs to be moved from Visual Studio 2005 to Visual Studio 2012/2013. The conversion to a high-end database server will improve the performance of TeamSpirit such that it can handle more concurrent users. Database performance problem is a major reason for the limited use of current system so far.

I am happy to report the redeveloped of the system has been competed during my sabbatical and a draft of a paper with architecture design and empirical data is attached below.

II. Working Paper Completed During Sabbatical

Facilitating Virtual Teams Using a Web-based GDSS

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draft version

Facilitating Virtual Teams Using a Web-based GDSS

Abstract

Virtual teams are increasingly becoming the key organizational units that carry out critical tasks. Earlier group decision support systems (GDSS) implementations do not support virtual teams whose members have to work in different places and mostly asynchronously. Web-based collaboration tools enable teams to work effectively in geographically dispersed places. A Web-based GDSS, called TeamSpirits, is developed to integrate creative problem solving approach and techniques to support virtual teams. The design and implementation of TeamSpirits are presented with emphasis of its facilitation function. An empirical study exploring the impacts Web-based GDSS on team effectiveness is discussed. In our study, we found that TeamSpirits can be used by self-facilitated virtual teams effectively and easily. Facilitators of virtual teams often communicate with team members by email messages. Messages linking task performance to its rewarding system and reminding messages sent to non-participants increased team's participation in group activity. The implications of our findings and future research directions are presented.

Keyword: Virtual Teams, GDSS (Group Decision Support Systems), CPS (Creative Problem Solving), Facilitation

1 INTRODUCTION

Virtual teams are geographically dispersed groups of people sharing a common goal to carry out interdependent tasks while working at different locations. Companies are deploying virtual teams using collaboration technologies to carry out short- and long-term projects to become agile enterprises [8, 25, 29, 30]. An MCI study in 2001 found that 61% of employees in companies with at least 500 employees have participated in virtual project teams [27]. The average virtual team size is 6, a relatively small in size. These teams met on average once each week using tools such as e-mail and audio-conferencing. Most workers (95%) who have participated on virtual teams found the experience productive and enjoyable.

In 2005, Intel found that that its employees often work with multiple teams in a virtual setting, their team members usually located at different time-zone and English language is not their native language [28]. 77% participate in phone meeting and there are 25.7 million audio conferencing minutes per month

[20]. Intel also started to support an enterprise-wide instant messaging system since 2005 by enforcing a clear usage guideline, security restrictions, and training. As a result, Intel has improved communications, accelerated decision making, and made meetings more effective [20].

With the omnipresence of broadband Internet connection in recent years, virtual teams have started to use emerging Web-based collaboration tools such as voice-over-IP phone, instant messaging systems, and Web-based group decision support systems (GDSS). Web-based GDSS is an extension of traditional GDSS with Web-enablement. It can complement other collaboration tools and is particularly appropriate for supporting a complex and structured group problem solving process involving virtual teams.

There are challenges in designing a Web-based GDSS that worth further exploration and the actual experiences in using such a system in laboratory and field settings will also provide us with additional insights for improving Web-based GDSS and for guiding the facilitation of virtual teams. In this paper, we try to address the systems design and facilitation issues of a Web-based GDSS. Section 2 is a detailed discussion of challenges in using Web-based GDSS in support of small virtual teams. Section 3 presents the architecture and design of TeamSpirits, a Web-based GDSS we have developed. Detailed design of group tools in TeamSpirits is presented in Section 4. An empirical study exploring the impacts of TeamSpirits usages and facilitation styles on virtual team effectiveness is discussed in Section 5. The implications of our findings and future research are discussed at the conclusion section of this paper.

2 CHALLENGES IN DESIGNING AND USING WEB-BASED GDSS FOR VIRTUAL TEAMS

Traditional face-to-face GDSS got a lot of attentions in the academic community in the early 90s [11, 15], but these GDSS products had very limited success in practices [11]. This may be due to the following reasons: (a) It is quite costly to deploy and maintain the infrastructure to support the GDSS operations including dedicated electronic meeting room, hardware, and software are quite high. (b) Most face-to-face electronic meetings require professional facilitators to run these meetings and it is very

expensive and difficult to acquire such facilitation supports. (c) The face-to-face limitation makes it difficult for virtual teams that have members dispersed in various locations to use these products. With these barriers, wide-spread usage of GDSS products that only run on local area networks has not been realized.

With emergence of Web-based GDSS, we may be able to remove the barrier for GDSS adoption and implementation in organizations. First, with a hosting solution, it is cheaper and easier to deploy Web-based GDSS. For a Web-based GDSS to support virtual teams, it must be designed to overcome the barriers of time and space that separate members of virtual teams [16, 25]. In a virtual team, the team leader often plays the role of a facilitator to manage the group decision making process, coordinate tasks, and communicate with members to give them clear instructions and to provide them with proper feedbacks about their online activities. Field studies indicate that facilitation directly affect the success of GDSS usages in the context of the face-to-face setting [6, 7]. However, existing literatures on facilitation of virtual teams are often related to computer conferencing system, online forum, or virtual communities [1, 18, 19, 40]. Little research has been done to study the impacts of Web-based GDSS and facilitation on virtual team effectiveness [41].

Most of managers are in tens or hundreds of meetings every month and they often spend more that 50% of their time in meetings. Most likely they will not have access to facilitators for most meetings [9]. It is even less likely that online meetings of virtual teams will be facilitated by professional facilitators. The creative problem solving process and the group techniques used by facilitators are the key factors that may contribute to the team effectiveness [9]. However, traditional GDSS products are used mostly in face-to-face setting and rely on in-person facilitators to conduct these meetings. When small virtual teams use Web-based GDSS, they may not be able to afford a professional facilitator to conduct these online meetings. Therefore, it is very important to build features into Web-based GDSS so that typical team members can be easily trained to perform the facilitation function.

For virtual teams, the facilitators should be conscious about the differences in work hours, time-zone, and individual schedules of team members. Longer duration should be given to each group activity

(comparing to face-to-face scenarios) to accommodate the team members. Since there is no physical public screen to draw all team members' attention, the facilitator should constantly remind participants to join a particularly online activity when it is about to begin, follow up with participants based on their online participation, ask them to paying attention to a particular group results.

Many collaboration tools that support virtual teams 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 [14], focus on support project teams' document sharing. Discussion forum, email, or instant messaging systems support group communications only. Some of these collaboration tools may have some isolated support for group techniques such as voting or idea generation (such as a team Web portal product). A Web-based GDSS should have explicit and direct support for the a group problem solving process, a comprehensive set of group tools, and a mechanism to integrate information generated by group tools with each other within the group problem solving process. Section 3 and 4 present the design and implementation of such a Web-based GDSS.

3 TEAMSPIRITS: A WEB-BASED GDSS FOR VIRTUAL TEAMS

Many Web-based collaboration tools have become enablers for effective functioning of virtual teams, small and large. We have developed a Web-based GDSS, called TeamSpirits, to support group problem solving and decision making with generic group problem solving tools so that it can be used by teams working at anytime and anywhere. Bostrom, Anson, and Clawson proposed a facilitation framework [6]. In this framework, collaboration technology is considered to be one of the "facilitation sources". From the onset, we have built several facilitation functions in TeamSpirits so that it can be easily used by members of a virtual team to create and manage their own online meetings so that no professional facilitators are required.

This research is grounded in design science [2, 17, 26, 31] which integrated systems development effort with empirical studies such as case study, laboratory experiment, and field study to justify, evaluate, and evolve the system. The design of TeamSpirits has been guided by CPS theories [32] and existing

GDSS research and development [11, 12, 13, 15]. The emergence of virtual teams in the global outsourcing environment and omnipresence of Internet and Web infrastructures are driving the development of our Web-based GDSS [36, 39]. The architecture design provides direct support of the CPS process and tools, commonly used in general problem solving and decision making. We have conducted more than 150 online meetings with participants ranging from 3 to 30 participants. More then 5 universities and 4 companies have used the system in various capacities. Users and facilitators from these organizations have provided valuable feedbacks to improve the system. Architecture and designs of TeamSpirits with features that are specifically built to support virtual teams are presented in this section.

We have designed and implemented a Web-based group problem solving systems, i.e., a Web-based GDSS, to provide direct supports for virtual teams in complex problem solving processes. The architecture design of TeamSpirits is influenced by creative group problem solving processes and theories and is depicted in Figure 1.

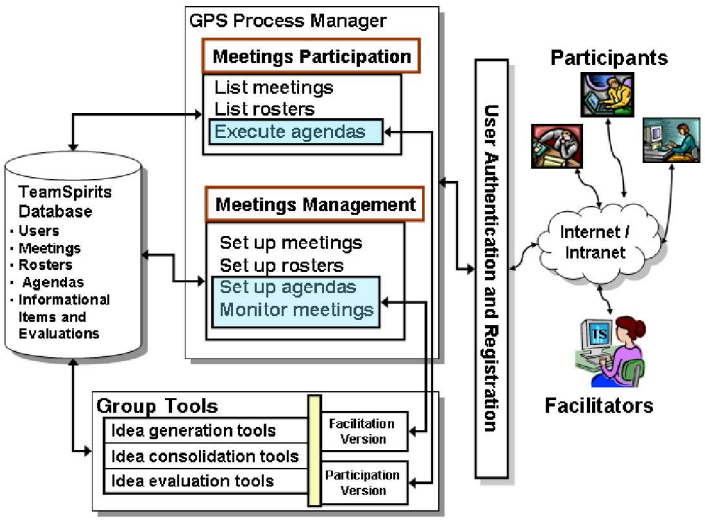

Figure 1 Conceptual Architecture of TeamSpirits

In TeamSpirits, we use the term online "meeting" metaphorically to represent a group problem-solving process for the specific problem at hand. A meeting consists of an agenda and a roster. A roster contains a list of users who are invited to participate the meeting by the facilitator of the meeting. A meeting agenda consists of a list of agenda items and each agenda item represents a group activity

supported by one of the group tools built into TeamSpirits. Every TeamSpirits user can create a meeting; hence he or she becomes the facilitator of the meeting.

The agenda in TeamSpirits is a mapping of the group problem solving process to a sequence of group activities supported by appropriate group tools in TeamSpirits. Meeting participants can join an active group activity by clicking on an agenda item from a meeting agenda (i.e., an executable agenda) to invoke appropriate participation version of a group tool.

TeamSpirits is designed to support the Creative Problem Solving (CPS) processes and self-facilitated virtual teams. Users of the system can create meetings and facilitate these meetings as facilitators. The facilitator of a meeting can invite existing TeamSpirits users to join a meeting as participants. One of the design objectives of TeamSpirits is that any user can facilitate meetings. This is an important feature for virtual teams who may not be able to afford the service of a professional facilitator. However, facilitator training of traditional GDSS takes about 2~3 days. How to reduce the requirements for facilitation training has become an overriding concern in our design of TeamSpirits to ensure that the system can be used by typical users with minimum training. In this section, we discuss design issues and features in TeamSpirits addressing the needs of virtual teams' group decision making as well as challenges in facilitating virtual teams.

The architecture of TeamSpirits includes several major components. These components are:

1. User authentication and registration function: A form-based authentication scheme is used to ensure that users have logged in with proper user name and password. Users who try to access other functions without logging in first will be detected and forwarded to the login program. New users can register themselves online, or they can be registered by a meeting facilitator.
2. CPS Process Manager: CPS Process Manager is a software shell that has two major functions to support users to participate in meetings and to manage meetings: (a) **Meeting participation function**: It is used by meeting participants to view a list of meetings that 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 participants of a meeting). From the meeting agenda, a list of agenda

items is displayed indicated the activity type, starting and ending time. An example of the meeting agenda is shown in **Error! Reference source not found.**. The sequence of the agenda items is determined at the beginning time of each activity in the agenda. Each agenda item is linked to a group tool to support a group activity. By clicking on an agenda item, the participant invokes the ***agenda execution*** program to invoke the participant version of a group tool so that the user can participate in this group activity. (b) **Meeting management function**: A facilitator can use this function to set up a meeting. Meeting management involves setting up and monitoring meetings and it includes the following tasks: (1) Create basic meeting information and a meeting agenda which consists of a list of agenda items. (2) Each agenda item representing an activity support by a group tool may need additional setup such as anonymity setting in brainstorming or the maximum value of a rating activity; (3) Invite existing users or create new users to participate in the meeting and then send email out to inform people that they have been invited to join the meeting. (5) Send email messages to remind people to join an activity when it is active or about to start. Facilitators also need to monitor the progress of ongoing activities in a meeting to remind people to contribute their ideas or to vote. (6) Another major task for the facilitator to perform is to set up initial informational items before a group activity is about to start. For example, a rating activity cannot be completed set up until a related brainstorming activity has finished.

3. Group tools: A set of group tools has been developed to support different type 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 meeting participants who are engaged in a meeting activity support by the tool; (b) a facilitation version that is used by a meeting facilitator to set up parameters or informational items associated with a meeting activity as well as to monitor the status of an ongoing activity. On

major effort by a facilitator during a meeting is to organize ideas generated from idea generation activities such that a list of consolidated ideas can be used for a follow-up evaluation activity.

4. TeamSpirits database: TeamSpirits uses a relational database to store all meeting related information includes meetings setup information, information created by idea generation tools, as well as evaluations submitted by meeting participants.

Facilitators and participants can manage or participate in meetings via an internet connection and a Web browser. The pure Web browser-based interface enables TeamSpirits to be used by members of a virtual team.

4 GROUP TOOLS: IMPLEMENTATION OF GROUP TECHNIQUES IN CPS

A set of group tools supporting various group techniques widely used in various stages of a CPS process have been developed. As depicted in **Error! Reference source not found.**, these group tools are classified into three categories to creative problem solving techniques which are often used in tandem: idea generation, idea consolidation, and idea evaluation [34]. A general CPS process includes the following steps [37, 38]: Identifying and stating the underlying problem; Produce and evaluate alternative and solutions; Planning and implementing the selected solutions. Group tools in these three categories can be used repeatedly to support each of the steps in the CPS process. For example, an idea generation tool can be used by all team members to identify all possible causes of a problem. After all these ideas been collected, the facilitator can consolidate these ideas so that they can be used by an idea evaluation tool. Once the root causes of a problem been defined, one can use the set of groups to produce and evaluate alternative and solutions. Since these group tools are designed to support generic group activities, they can be used in a wide variety of team tasks. The facilitator needs to set up each group tool used by an agenda item to provide the proper context for the specific group activity.

A common set of common functions is accessible as a navigation bar places on top of each group tool to allow users (a) to view a list of invited or managed meetings, (b) to view the agenda of the current

meeting, and (c) to display meeting roster. From the meeting roster tool, a participant can send an email to other participants. Participants can easily switch to facilitation mode to set up a new meeting and manage meetings they have created.

Each group tool has a participation version and a facilitation version. The participation version of a group tool is used by meeting participants to input ideas or evaluate ideas. The facilitation version of the group tool is used by facilitators to enter basic information about the activity, to determine various options or parameters for a particular activity (e.g., rating's range, anonymity setting of brainstorming), and to import data from other activities, and organize data generated by the participants. A group problem solving process can be conceptualized as a sequence of group activities. Group problem solving techniques such as brainstorming and various evaluation techniques are implemented as group tools to support these group activities. These group tools are discussed in the following.

4.1 Idea generation Tools

There are several tools that allow participants to input and share their ideas, opinions, or information. These tools support divergent thinking in the creative problem solving process. Currently, TeamSpirits implements four tools in this category:

1. **Brainstorming tool**: Many GDSS systems emphasize anonymity and have shown some benefits for group working in an anonymous environment. TeamSpirits' Brainstorming tool can be set up by the meeting facilitator in three modes: (1) True anonymous (name of the creator of an idea is not recorded or displayed), (2) semi-anonymous (name is not displayed among participants, but is recorded in the group repository and shown to the meeting facilitator), (3) Non-anonymous (user name is recorded in the system and is shown to all participants). Newly generated ideas by a participant or others will be highlighted to encourage the participant paying attention to them.
2. **Structured Brainstorming tool**: The Structured Brainstorming activity allows participants to brainstorm ideas from multiple perspectives (i.e., different trains of thoughts). This Structured Brainstorming encourages lateral thinking. It is a creative thinking principle proposed by de Bono

who argues that problems should be studied from different perspectives before one tries to solve them [10]. The meeting facilitator needs to set up a set of categories (i.e., different aspects of an issue under discussion). For example, in the context of business strategic planning using SWOT analysis, the facilitator can create four categories: strengths, weaknesses, opportunities, and threats. A participant needs to select a category to be associated with an idea before the idea is submitted.

3. **Discussion Forum tool:** In our field studies, we found that many users of TeamSpirits are familiar with the use of various Web-based discussion forums. Discussion forum encourages a conversational-style dialog among participants. Any participants can post a new topic and all participants can post messages to existing topics. Therefore, facilitators encourage participants to use the Discussion Forum as a simple group writing tool to collect participants' thoughts in writings to serve as a basis for drafting a report.
4. **Information Sharing tool**: By sharing information (URLs of web resources or uploaded documents) to build mutual knowledge is important to help virtual teams to work together effectively [8]. It can be used to establish a shared context of the online resources during the group problem-solving process. This is an important feature that is very useful for long-lasting online meetings.

4.2 Idea Organization Tools

Using idea generation tools such as brainstorming tool, a group can generate many ideas in a short period of time. These ideas may contain similar or duplicated items. Some irrelevant items need to be removed. Some last minute new items can be added. Idea consolidation is mainly the responsibility of the facilitator in a distributed environment and can be done during the initial set-up process of idea evaluation tools. This can be a challenging task for the facilitator. Currently there is only one idea organization tool, called Idea Consolidation tool, in TeamSpirits as depicted in Figure 2.

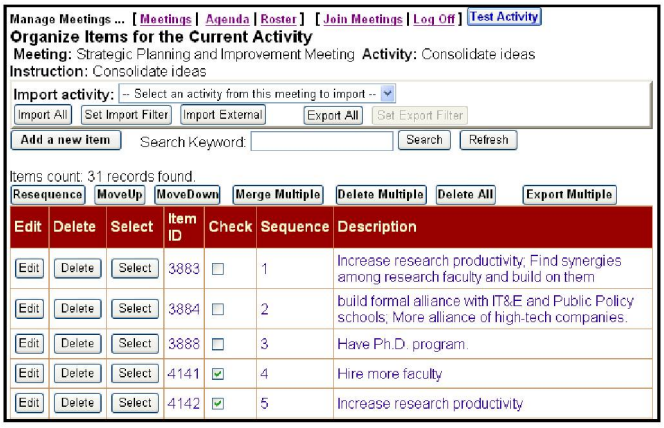

Figure 2 Idea Consolidation Tool in TeamSpirits

This Idea Consolidation tool can be used by the facilitator to import data from other activities while meeting participants can view the current consolidated list of items and send their suggestions for further consolidating by email to the facilitator. When the involvement of all team members is desirable during the consolidation process in a distributed environment, the use of the consolidation tool is recommended. A consolidation tool can be used to support convergent thinking process. A simple search function is implemented. Ideas contain the same keywords can be retrieved by the facilitator to determine whether they should be merged or deleted.

In virtual teams, idea organization activity is probably the most difficult task to facilitate. A facilitator can certainly work with group of participants in a face-to-face meeting to discuss how ideas generated so far should be organized and consolidated. Ideas been generated may have the following relationships with each other and actions should be taken by the facilitator to consolidate them:

1. Similar ideas: Similar ideas should be combined by either removing a duplicated idea or creating a more generic idea to represent all similar ideas. Using the search function for common keywords in the Idea Organization tool is a quick way to identify ideas that are potentially similar.

2. Ideas at different levels of abstraction: When two ideas that are similar but at different levels of abstraction, the facilitator should merge the more detailed idea into the abstract one in most situations.

3. Irrelevant ideas: Ideas sometimes may be entered by participants as jokes or entered incorrectly because of their misunderstanding of the brainstorming triggering question; hence, they are irrelevant to the task at hand. The facilitator should just remove these ideas.

The import and export facility as well as consolidation function is built in each of the facilitator version of a group tool. Therefore, it is not necessary to set up a separate idea organization activity in the group decision making process, unless you want more intensive involvement from members of a virtual team. Working with virtual team members in asynchronous mode to consolidate ideas is a very challenge task. The facilitator may want to use audio-conferencing or video-conferencing in conjunction with TeamSpirits' to perform this task.

4.3 Idea Evaluation Tools

There are four evaluation tools currently been developed in TeamSpirits including: Rating, Ranking, Selection, and Multicriteria Evaluation tools. Participants can submit their evaluations or votes. They can also view group results that include group averages and standard deviations. Higher standard deviation is an indication that there is a lack of consensus on an alternative or issue. The facilitator can bring those issues that have high standard deviation to participants' attention and initiate more discussions to have different views of the issue heard. The participants can recast their votes based on these additional discussions to see whether the team can converge to a consensus.

Idea evaluation can be viewed as a process of building consensus. The group averages of members' ratings or rankings should not be taken by their face values to make the final decision. The facilitator and meeting participants should use the standard deviation of the group result as a measurement of group consensus. Additional group discussion or debate should be conducted; then ask the team members to recast their votes to see whether the group can reach better consensus.

5 AN EMPIRICAL STUDY OF SELF-FACILITATED VIRTUAL TEAMS

When a Web-based GDSS is used by a small virtual team, it is most likely that a team member will facilitate their own online meetings [41]. To study whether TeamSpirits can use effectively and easily in such context, we conducted an experiment to study the effectiveness of self-facilitated online meetings using TeamSpirits.

In this study, there were 10 teams each in the experimental group and the control group. Each group was required to work on a business plan and to submit a final report for extra credits for a class within one month. All team members in the experimental group were given one-hour training to become a facilitator. 10 teams in this group were asked to use TeamSpirits to support the creation and writing of a business plan. Any team members could take initiative to create meetings and invite other members to participate these online meetings. In contrast, teams in control group did not have access to TeamSpirits and they were still required to submit their final reports. We did not capture the face-to-face meeting minutes of the control group.

Table 1 The result from the self-facilitated virtual teams study

Group	Team#	Size	Final Report Com-pleted	Use Team-Spirits	Meeting Goals	Word Counts of the Final Report	Final Score (out of 100)
Experi-mental Group	1	6	√	√	Naming the company; Create new product ideas; Naming the new product; Determine target markets; Define market strategies, pricing, and after sale service.	1,367	76
	2	6					
	3	5	√			7,850	86
	4	6	√	√	New business ideas; target markets	3,070	80
	5	5	√			6,421	85
	6	6	√	√	Company name; Products; Marketing strategies; Customer services; Product Functions; Product styles	8,240	88
	7	5	√	√	Company name; Product names	2,694	85
	8	5	√	√	Company name	5,678	83

	9	5	√	√	Company name; Product names	2,184	82
	10	5	√	√	Company name; Product names	2,204	78
Control Group	1	3					
	2	4					
	3	3					
	4	4					
	5	4					
	6	3					
	7	3	√			1,428	78
	8	4					
	9	4	√			585	70
	10	4	√			2,704	72

The results from the experimental group and the control group are summarized in Table 1. 9 out of 10 teams in the experiment group turned in their final reports, and among which 7 out of the 9 teams used TeamSpirits to support the task assigned. 1 to 6 online meetings were conducted by these teams that used TeamSpirits. These meetings were used to resolve issues such as determining the new company's name, creating the new product ideas, formulating marketing strategies, and defining service offerings. By comparison, only three teams within the control group submitted their final reports. The completion rate between the experiment group and control group is 90% vs. 30%. The completion rate of teams in the experimental group that used TeamSpirits is 100%. The reasons the experiment group achieved higher completion rate may be due to the following reasons:

1. Team members can easily meet online day and night that give they more time and opportunities to interact.
2. The teams that used the system were implicitly forced to conduct their meetings in a structured way following the CPS process which might contribute to the increase in creativity and productivity.
3. The team members' ideas and evaluation results were recorded in TeamSpirits and these results could be easily obtained by the users to be incorporated into the final reports.

The average words counts of the reports submitted by teams in experiment group (M=4412, SD=2645.19) is much higher than the control group (M=1572.33, SD=1066.85). These reports were graded by two instructors who did not know whether a team used TeamSpirits or not. The reports were graded in terms of contents, structures, rigorousness, and creativities of ideas. The final average score for

the reports for teams in experiment group (M=82.56, SD=3.94) is also higher then the ones in control group (M=73.33, SD=4.16).

Within the experimental group, three teams chose not to use TeamSpirits, but two of the three teams still turned in their reports with high average words counts and received relative high score in their final reports. One possible explanation is that these two teams had received TeamSpirits' facilitation training; therefore they might be using the CPS concepts embedded in TeamSpirits in their traditional face-to-face meetings. As the result, they achieved relative high performance. There were 3 teams out of the 7 teams that used TeamSpirits reported that they also used face-to-face meeting to complete their projects when they tried to finish the writing of the final project reports.

One goal of this study is to find out whether we can easily train team members to use TeamSpirits to conduct their own online meetings in small virtual teams. We analyzed the actual online meeting data of the 7 teams in the experimental group to study the actual usage patterns of TeamSpirits by self-facilitated teams. The result is summarized in Table 2.

Table 2 Summary of TeamSpirits Usages in the Experimental Group

Team#	1	4	6	7	8	9	10	***Average***
Size	6	6	6	5	5	5	5	***5.43***
# of meetings	6	2	5	2	1	2	2	***2.86***
Average # of Agenda items	2	1.5	2	1	2	2	2	***1.79***
Average # of group tools used	2	1.5	2	1	2	2	2	***1.79***
Average # of active participants	2.3	3	5.2	2	3	2	1.5	***2.71***
Average percentage of participation rate	38%	50%	86%	40%	60%	40%	30%	***49%***
Average # of ideas generated in each meeting	10.67	4.5	23.67	3.5	4	3	5.5	***7.83***
Average # of ideas generated by each active participant	3.54	1.15	4.2	1.75	1.3	1.5	3	***3***
Words count of final reports	1,367	3,070	8,240	2,694	5,678	2,184	2,204	***2,204***
Final score	76	80	88	85	83	82	78	***78***

On average, each team held 2.86 meetings (ranging from 1 to 6). 4 out of the 7 had two meetings throughout the project duration. The average number of agenda items (i.e., group activities) is 2.79 (ranging from 1 to 2). Only Brainstorming tool and Rating tool were used. The depth of these meetings as measured by the number of group activities in each meeting was limited. This can be partially explained because 6 out of 7 teams set up more than one meeting for the whole project. We found that not all team members participated in these group activities. The average number of participants for each meeting ranged from 1.5 to 5.2 members. This can be translated to average percentage of participation rate (i.e., average number of active participants per meeting divided by the team size) ranging from 38% to 86%.

The average numbers of ideas generated in each brainstorming activity is 7.83 (ranging from 3 to 23.67). The average numbers of ideas generated by each active participant is 3 (ranging from 1.15 to 4.2). There is no clear correlation between participation rate and average numbers of ideas generated by each active participant. Overall, Team#6 has the highest average numbers of ideas generated in each meeting and by each active participant. It also has the highest average number of participants per meeting and the highest participation rate. This team also has the highest words count for its final report and received the highest score.

Only one team member in each of the 7 teams was designated by their teams to create the meetings and facilitate these meetings. This study shows that even with very basic facilitation training, an inexperience facilitator can still manage online meetings to achieve effective outcomes. Teams that used TeamSpirits have much higher rate in completing the assign tasks. Overall, the average percentage of participation rate in online activity is a good indicator of virtual team's performance. Therefore, how to increase team member's participation in online meetings has become an important issue worth further studying. The second study discusses in Section 5.2 was designed to find out how a facilitator should use email messages to communicate with members of a virtual team to increase their online participation.

6 Conclusions

GDSS had been thoroughly studies during the 1990s; however, the adoption of GDSS in practices has been limited. Traditionally, GDSS has been used in face-to-face group decision making facilitated by professional facilitators. A good facilitator usually requires an intensive training on the software tools and facilitation skills in addition to many years of practical experiences. However, maintaining a dedicated group decision room to house the LAN-based GDSS systems and the hiring of a professional facilitator can be quite expensive. Therefore, the costs of using GDSS for group problem solving can be quite high. This is the main reason that the actual usage of GDSS may not have been as high as expected. With the advent of Web technologies, it is possible to build and deploy cost-effectively a Web-based GDSS.

There are many factors affecting the effectiveness of virtual teams when they use various collaboration tools. These factors may include team member's prior online collaboration experiences, task types, rewarding systems, member's language skills, and cultural backgrounds. Web-based GDSS can support a virtual team to solve complex problems using a CPS process. However, the facilitator of an online GDSS meeting most likely will be a member of the virtual team. He or she often needs to rely on email messages to provide instructions and feedbacks to team members when conducting online meetings asynchronously. One major challenge of managing these meetings is that the facilitator can neither observe participants' body languages nor monitor their activities in real time continuously. In this research, we have tried to address some of these challenges using the design science approach. We first designed and developed TeamSpirits, a Web-based GDSS. And then we validated the efficacy of the system by conducting two empirical studies.

The TeamSpirits presented was designed to ensure that typical users can be easily trained to manage and facilitate online meetings. We have discussed the design and functionality of the system that are

relevant to group decision making and online facilitation in the context of virtual teams. We found that TeamSpirits can be used by self-facilitated virtual teams effectively in our first empirical study. In our second study, we found that different types of feedback email messages sent by the facilitator to virtual team members can affect the effectiveness of virtual teams. Messages linking the task performance to reward did not increase team's participation in group activities or their perceived team effectiveness significantly. Sending reminding email messages to participants who did not actively participate in a group activity had a significant impact to the actual participation of team members. As the result from our empirical studies, we are considering add a new function to TeamSpirits to allow it to send out a "reminder" email announcement automatically before the beginning of a group activity. We also would like to enhance the monitoring function in the facilitator-version of each group tool so that the facilitator can easily review the activities of meeting participants and to communicate with them more effectively.

Based on our research, we found that the users of TeamSpirits on average believe that a Web-based GDSS system can be very useful in supporting virtual teams. We also found that no one tool can meet all virtual teams' collaboration needs. Virtual teams often have taken a mix-and-match approach to collaboration technologies usage [24]. We are planning to study when and why virtual teams choose to use different types of collaboration technologies and to analyze the effectiveness under these situations. One may assumes that using GDSS in asynchronous mode will give participants more time to "sit" on an issue so that they can be more productive or creative. However, some participants expressed the lack of instant feedbacks from other participants as a lonely experience when they were engaged in an online group activity by themselves. We are planning to compare the differences in using TeamSpirits by virtual teams under synchronous mode versus asynchronous mode to see whether having other team members working at the same time may create enough excitement to affect the virtual team's performance. We also want to further investigate the impacts of complementing collaboration technologies such as a voice-over-IP audio conferencing system in conjunction with TeamSpirits on virtual team's effectiveness.

These additional studies may help us understand better how to facilitate virtual teams with proper mix of collaboration technologies and group processes [23].

Acknowledgement: This research is sponsored in part by National Sciences Council, Taiwan, ROC, Grant# NSC92-2416-H-005-020.

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