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Technical and Environmental Challenges of Collaboration Engineering in Distributed Environments

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Abstract. Collaboration in distributed settings has become a reality in organizational life. Yet we still have much to learn about issues inherent to distributed collaboration. One important area of study is the integration of Collaboration Engineering in distributed virtual teams for helping them in structuring their interaction. The field of Collaboration Engineering offers promising guidelines for process structures, but its application in distributed arenas is just beginning to be studied. We report on the design and development of a new collaboration environment for the incorporation of Collaboration Engineering principles, as well as the results of an initial study that examined leadership and process structure effects on the development of shared understanding. The paper describes the research motivation, the environment, and the results of the study, including an analysis of participants' feedback and their message exchanges. We discuss both technical and environmental challenges for research on Collaboration Engineering in distributed environments.

Keywords: Collaboration Engineering, Virtual teams, Shared understanding, Process structure, Leadership, thinkLets.

1 Introduction

The increasingly important phenomenon of virtual teams and distributed work has provided fertile ground for research. A growing body of knowledge is developing through examination of topics such as trust, communication, participation, coordination, and effectiveness, to name a few [1], [2]. In addition, technological support for distributed teamwork has evolved considerably in the last decade, with a wide variety of environments available [3], [4]. However, one of the most significant challenges from traditional teams still remains an issue in distributed environments. This persistent challenge is team process, namely the processes that team members need to use for maximum effectiveness in accomplishing different tasks. We also need to learn much more about which types of support tools and structures can be provided for team members so that they can select and carry out appropriate processes without having to depend on a facilitator.

Collaboration Engineering methods and techniques have been developed to address this important issue, via the capture and design of successful repeatable collaboration processes [5]. Collaboration Engineering began in the context of same-time same-place meetings, addressing design of recurring collaboration processes that team members could use to reach their goals. The methods and techniques of Collaboration Engineering have not yet been applied in distributed situations to any great extent. Yet it is precisely in virtual teams that such process structure is likely to require even more attention.

The purpose of this paper is to advance the concepts and application of Collaboration Engineering in virtual environments via a specific implementation and example. The paper describes the design and development of a new environment for supporting process use in virtual teams. We also report the results of an initial study that was conducted in that environment. The study was designed to examine concepts that have proved both important and especially difficult in virtual teams, namely the achievement of shared understanding through process use and leadership.

The paper contributes in several ways. First, conducting research on virtual teams is challenging on several fronts, since researchers have to rely on effective communication among participants scattered in different places who are dependent on technology as the means of achieving shared understanding. Indeed, some have argued that attaining shared understanding is a necessary precondition to collaborating at all, since people cannot collaboration or agree if they do not understand what it is they are collaborating or agreeing [6]. Achieving shared understanding among participants on a team, for instance, will require effective communication and coordination [7]. However, establishing communication and coordination among voluntary participants is challenging, and we provide an examination of how such challenges occur and might be mitigated. Second, we show how the successful method of Collaboration Engineering from face-to-face environments translates to virtual teams, in order to address important concepts that are particularly difficult in distributed work. Finally, the results of the initial study reveal both technical and environmental issues and how they might be addressed for more successful design and implementation of virtual environments that incorporate team processes.

Section 2 provides the conceptual background for Collaboration Engineering and the key concepts that were examined in the initial study. Section 3 describes the technology and process environment that was designed and implemented for this research. Section 4 describes the initial study that was conducted in the virtual environment, and Section 5 examines technical and environmental issues for research. Section 6 concludes with a summary analysis of the contributions and directions for future research.

2 Conceptual Background

Powell et al. [1] define virtual teams as "groups of geographically, organizationally and/or time dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks" (p. 7). While virtual teams offer many benefits to organizations, such as flexibility, adaptability, and responsiveness, they also face many challenges in coordination and communication [1], [8]. Among other issues, virtual teams experience difficulty in establishing relational links and shared understanding. To overcome these challenges, we argue that virtual teams can rely on leadership and purposeful team processes, supported by appropriate technology.

2.1 Challenges in Virtual Teams

Virtual teams have a high degree of reliance on information and communication technology (ICT) [9]. The lack of face-to-face interaction may increase efforts to foster interaction, inclusion and participation [10], as well as to integrate channels for sharing social information that could lead to development of strong relational links that can take longer to develop in a virtual team [11]. Based on McGrath's Time-Interaction-Performance (TIP) theory [10], the development of relational links in groups, or teams, involves performing activities related to member support and group well-being functions. As groups interact in one of McGrath's four modes of (1) inception, (2) solution, (3) resolution of conflict, and (4) execution of performance, they can perform one or more of three functions: (1) production function, (2) member-support function, and (3) group well-being function. A team with no past history, as is typical in much of the virtual team research, that is working on a challenging problem surrounded by technological and environmental uncertainty will have to engage in all three functions and in all four modes to avoid detrimental effects on performance [12].

Media synchronicity theory [13] builds on media richness theory [14] to argue that "the key to effective use of media is to match media capabilities to the fundamental communication processes required to perform the task" (p. 9) [13]. For this reason, it is unlikely that a single medium will excel in performing all the different tasks that teams face. Having a set of alternative media that can be switched for different tasks to be performed would be more appropriate for teams. Thus, a technology for supporting teamwork should offer a set of alternative media that can be utilized by team members in performing their tasks.

Sarker and Sahay [15] argue that virtual teams will go through several development phases, i.e., initiation, exploration, collaboration, culmination, and dissolution. Collaboration among members does not typically occur at initial contact. Instead, efforts are needed to move virtual teams from initial or exploration phases to a collaboration phase, and some teams might simply fail to reach the collaboration phase. This developmental view of virtual teams creates a challenge for researchers who are interested in collaboration among virtual team members because it requires an investment of time and effort in observing virtual team activities. A short-lived virtual team, such as is often used in laboratory experiments, could lead to misleading conclusions regarding collaboration activities in virtual teams.

2.2 Purposive Processes through Collaboration Engineering

Collaboration Engineering is a field that directly addresses the process challenges of collaborative work in a systematic way. The cornerstone of Collaboration Engineering is the design and development of a set of process objects called thinkLets, which taken together can be considered a Collaboration Engineering pattern language [16]. A thinkLet is "a named, packaged facilitation technique captured as a pattern that collaboration engineers can incorporate into process designs" (p. 1) [16]. Each thinkLet addresses a particular pattern of collaboration, that is, a generic activity that teams need to undertake in order to accomplish collaborative tasks. The instantiation of these patterns in virtual teams enables purposive process structures that can help teams execute collaboration processes and achieve predictable interactions among team members, and therefore assure better team performance.

Process structuring in virtual team collaboration often takes shape as *temporal coordination*. It has been argued that temporal coordination is an important success factor for virtual team collaboration. Temporal coordination involves the synchronization of team members' informational, decisional, and interpersonal behaviors [7]. It may also involve scheduling and the allocation of resources. In particular, temporal coordination can address the mechanisms through which a team communicates, as well as the sequencing of problem solving activities to perform the team's task [7].

Massey and colleagues studied how teams that used explicit temporal coordination structures performed in comparison to teams that did not use temporal structures. The teams with temporal coordination had a randomly assigned leader who received instructions about which steps to execute and complete in the team process at fixed points in time. The instructions specified exactly what the leader and team had to do, without being explicit about exactly how leaders had to go about their work. Teams that faithfully followed the prescribed temporal coordination structures appeared to display higher performance.

The interesting aspect of Massey et al.'s work is that it offers teams (and their leaders) the freedom to choose or sculpt their own communication processes while still prescribing an overall problem solving strategy. Their detailed analysis, however, reveals that much of the teams' performance actually depends on the way in which communication processes are carried out. Our research is a natural continuation of this line of investigation. We do not offer prescriptions on the level of an overall problem solving process; rather, we offer chunks of process support (thinkLets) that specify interaction patterns and leader instructions. In other words, we do not offer the 'what' but the 'how' and let the teams (or their leaders) decide for themselves about the 'what.'

2.3 Shared Understanding and Leadership

We have argued that development of shared understanding is essential and, furthermore, that coordination and communication are essential for the development of shared understanding. Two aspects that we argue could address the issues of coordination and communication among team members are (1) team process; and (2) leadership. By having structured process and leadership, team members should be able to initiate a process of achieving shared understanding through structured deliberations, discussions, information exchange, and guidance by a team leader. The critical role of leadership in a team has been recognized by most models of group and team effectiveness [17]. However, leadership is both especially difficult and important in virtual teams for several reasons. Leaders usually exercise influence face-to-face, and that capacity is lost in virtual environments [18]. Since team members are dispersed and disparate, leadership is especially important for bringing team members together. Furthermore, in the research on virtual teams, there is also a challenge to check whether team leaders really exercise their leadership role. In traditional teams, researchers can easily observe whether leadership roles are exercised by attending and observing team meetings. However, observing leadership roles in a virtual team requires the ability to control and access all available communication tools used by the team. Furthermore, researchers have to set strict boundaries on which communication tools can be used by team members in order to perform this observation.

To successfully empower distributed teams to work together, group members must be able to establish shared understanding. Shared understanding is a multi-dimensional construct that refers to task, team well-being, and member support – the three dimensions of the TIP theory referred to earlier [10]. In general, shared understanding means convergence on a common set of reactions to stimuli. From a task perspective, this means that a team will have a common view of what needs to be done to achieve their goal. From a team well-being perspective, it means that a team will have a common set of norms, expectations, and values. From a member support perspective, it means that team members will see how they individually fit within the larger collective in terms of their roles, knowledge, skills, and abilities.

Shared understanding is an evolving state. To reach shared understanding, teams must rely on team development and performance management, which is enabled through effective leadership [17]. Some empirical work has been done on leadership in virtual teams, e.g., both participative and directive leadership styles have been shown to be positively related to performance [19]. The phenomenon of emergent leaders in virtual teams has also been examined [20], with emergent leaders using more task-oriented messages than non-leaders in their virtual teams. Moreover, emergent leaders were found not to support the socio-emotional side of group development more than other team members. We can speculate that socio-emotional development is particularly difficult to do in virtual environments, yet it should be no less important.

Apart from the empirical research, a number of practical and conceptual papers argue for the importance of studying leadership within virtual teams. An expert review panel recommended specific behaviors and tasks for leaders in different phases of virtual projects [21]. Two essential tasks were the need to develop shared mental models within the team and the need to define roles. A comprehensive review of leadership and facilitation in GSS environments provides a number of future research directions, including studying interventions that promote the development of the human-machine system that a virtual team represents [18]. This work stresses the importance of the interaction of leadership characteristics or behaviors with technology and process.

2.4 Summary of Key Concepts

We have argued that virtual teams face unique challenges, one of which is achieving shared understanding. Effective use of process is one way that shared understanding can be achieved. Leadership within the team also is important and indeed might have a synergistic effect with process structure. The use of thinkLets that have been developed in the field of Collaboration Engineering provides a unique opportunity to put all these concepts together. The next section describes an integrated technology and process environment that we designed and implemented in order to support research on these concepts.

3 Technology and Process Environment

The design of the technology environment followed from the requirements to support team process and the overall goals of the research. We had the following design criteria for the collaboration technology:

1. Be able to implement all six patterns of collaboration, namely diverge, clarify, reduce, organize, evaluate, and build consensus [16];
2. Provide easy access for participants from anywhere in the world;
3. Be easy to use;
4. Incur relatively low, or no cost; and
5. Provide a valuable experience for student participants in particular, who could benefit from learning a new technology environment.

Since the fourth criterion implied the use or adaptation of existing software, we began by evaluating several existing technologies (Blackboard, Basic Support for Cooperative Work, GroupSystems™, and Intranets.com). Groove™ was chosen because it best met all five of the evaluation criteria and because it had not been previously used in this type of study, thus providing the opportunity to create a new collaboration environment with potential for adaptability in future work.

We designed and implemented a workspace in Groove™ (www.groove.net) that allowed team members to communicate issues, make decisions, and create their deliverables. The Groove environment supports a set of alternative media that can be utilized by team members in performing their tasks, in accordance with Media Synchronicity theory [13]. Groove can support synchronous communication through chat or asynchronous communication through discussion board and instant messages.

We implemented the following six project objects, i.e., thinkLets, in Groove, which cover the six patterns of collaboration that were referenced earlier (pattern name is in parentheses):

- LeafHopper: helps a team to gather ideas on a number of topics simultaneously (Diverge).
- FocusBuilder: supports a team in arriving at clearer descriptions of key ideas (Clarify).

- BroomWagon: helps a team to select what are the key contributions from a larger set (Reduce).
- PopcornSort: allows a team to organize a set of ideas into a set of categories (Organize).
- StrawPoll (3pt): lets a team take a vote on a set of proposals or options (Evaluate).
- CrowBar: helps a team to explore reasons why team members have differences of opinion (Build Consensus).

The thinkLets were chosen so that they would be useful for a broad set of tasks, but particularly the task in the initial study, and be fairly straightforward in terms of execution. Each thinkLet was implemented as a separate tool in Groove (see Figure 1). Each thinkLet tool was based on Groove's Outliner tool. Apart from the thinkLet tools, participants also had access to Chat and Instant Message.

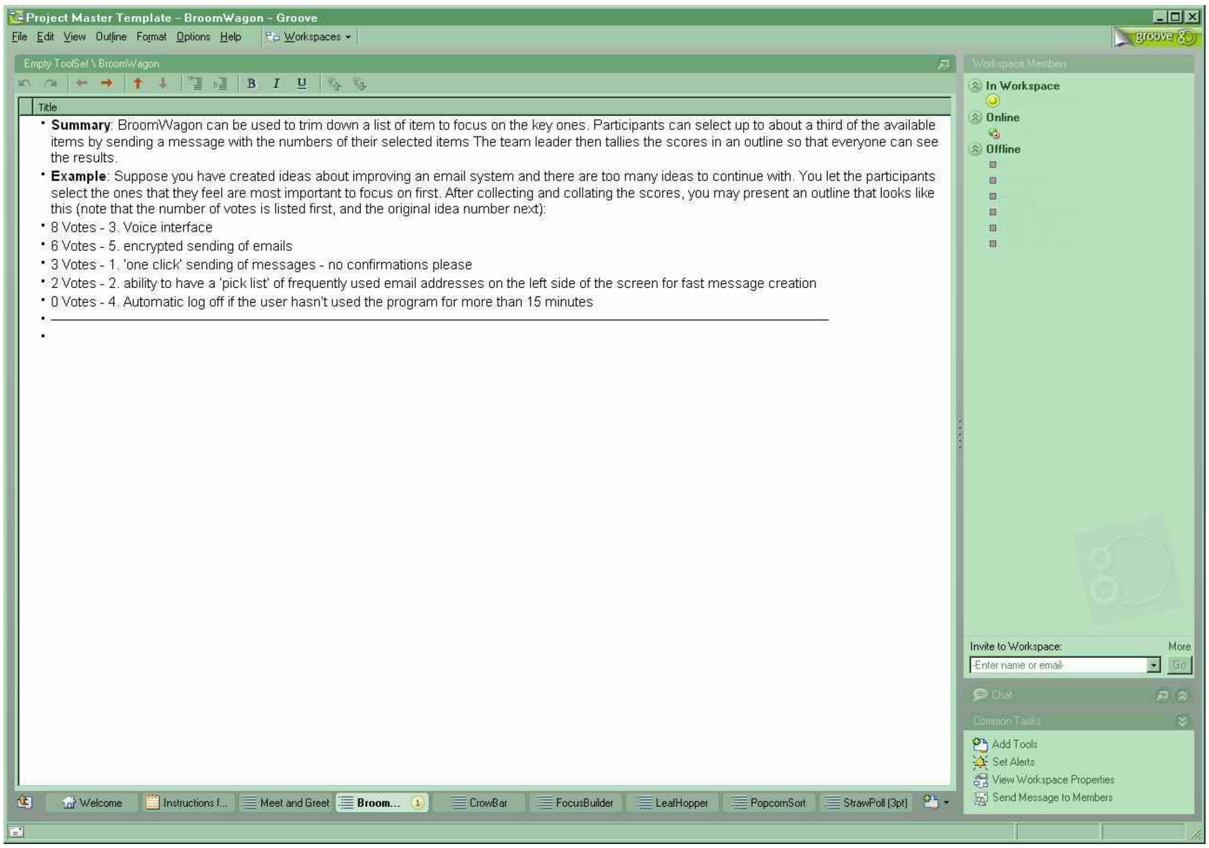

Fig. 1. ThinkLets as Separate Tools in Groove.

We provided three types of thinkLet guidance. First, the task materials included a high-level description for the types of activities that could be supported by each thinkLet. Second, each thinkLet tool in Groove included a template with sample information that illustrated what the results of using the tool might look like. Finally, a separate tool in Groove was populated with more elaborate instructions for each thinkLet. These instructions included guidance selection and a detailed step-by-step script that the team (or team leader) had to follow.

In an effort to accelerate the development of relational links, i.e., closeness or intimacy among group members, participants were provided an opportunity to introduce themselves in a forum called "Meet and Greet." Through initiating interaction in this forum, team members can "break the ice" and get to know their teammates better. This in turn can help them in performing not only the production function by focusing on the given task, but also the two other functions from McGrath's TIP theory, i.e., member-support function and group well-being function.

A virtual helpdesk was also set up and staffed by the research team for the initial study. Participants could send email to a single address and have their questions answered without delay.

4 Initial Study in the Distributed Virtual Environment

We conducted an initial case study of Collaboration Engineering in our distributed virtual environment in order to understand the best way to introduce Collaboration Engineering into virtual team work and the barriers for virtual teams in performing collaboration activities. Studies of Collaboration Engineering in virtual environments are relatively new. We found only one study [22] that tried to use collaboration engineering in a distributed setting, focused on designing and executing a process that could shorten the steps in a crisis situation. Our initial study was designed as a laboratory experiment with two treatment conditions related to leadership structure, i.e., assigned leadership and shared leadership. In addition, we were interested in how each team would utilize the collaboration tools provided to them for accomplishing their task. Much is still unknown about how collaboration tools can be integrated into virtual team work to achieve the goal of helping teams in collaboration processes. Choosing the right technology for a virtual team was a starting point for building virtual collaboration. The technology to be used should allow members to interact via a set of alternative media for performing their tasks. Technology that only supports one mode of communication, i.e., either synchronous or asynchronous, would not be an optimal technology for supporting virtual team work, as described by media synchronicity theory [13].

Our initial study involved fourteen five-member virtual teams working on a predefined task related to emergency response. Each team consisted of students from three different universities acting in pre-defined roles: government official, utility infrastructure superintendent, police officer, aid organization representative, and information system developer. Students were randomly assigned to teams in two different treatment conditions. We expected that different leadership styles would lead to different approaches in how teams would utilize available collaboration tools in performing their task. Those different approaches could also lead to different satisfaction levels and shared understanding among team members. Furthermore, as teams have a set of alternative media to choose from in performing their task, we expected each team to have different preferences in what media they were going to use. The choice of media for communication could be significant given the fact that teams were dealing with an urgent task that required rapid response. For example, a study about communication among clinicians in an emergency department found that synchronous channels of communication were used more frequently than asynchronous channels [23]. In our study, we expected that teams would utilize synchronous communication media such as chatting more than asynchronous media such as emails or a discussion board. To measure participants' perception of shared understanding and satisfaction, a questionnaire was administered at the end of the study.

4.1 Participation

Seventy students from three different universities in the U.S. agreed to participate in this study for an exchange of extra credit in the course in which the study was conducted. Their participation was voluntarily and they could drop out from the study anytime they chose to do so. An alternative way to earn the extra credit was offered by course instructors, in accordance with guidelines of the Institutional Review Board. In order to earn the extra credit through this experiment, participants had to perform all steps instructed by the researchers. Those steps included (1) answering a pre-session question dealing with their understanding of the given task; (2) joining their teams in the Groove workspace; and (3) answering the post-session questionnaire at the end of the study. In this initial study, we did not take into consideration the participation levels, role fulfillment, or quality of team deliverables. Furthermore, we did not penalize those who joined their teams at the later stage of the study. Our goal for this initial study was to encourage as many participants as possible to join their teams, while minimizing the number of drop-outs.

4.2 Task

Teams were asked to come up with specifications that could be used to develop a website to assist people working in a disaster relief situation. The fictional scenario of the disaster was adopted from Santanen's research [24] on formation of creative solutions using electronic brainstorming. This scenario described a natural disaster striking a small island nation that caused an emergency situation. In our study, the task of the virtual team was to provide assistance to an information system developer who was in charge of developing a website to assist emergency response teams in the disaster area. Teams needed to deliver a specification that could be used by the developer as guidance in developing this website. However, to introduce realistic constraints and the need for discussion and consensus, the teams were limited to a small number of features that could be incorporated into this new website. Teams had one week to perform this task and turn in their deliverables.

4.3 Team

A team consisted of five people playing five different roles, and each role was relevant to people involved in emergency relief effort. Upon joining their team, members were instructed to introduce themselves by posting information about themselves on a "Meet and Greet" forum. Collaboration within the team was necessary because each role represented a different constituency or agency that had different preferences for what should be included in the team's deliverable. Since the deliverable could have only a limited number of items and those items had to be prioritized, team members would have to collaborate to find the best way to integrate their incongruent goals, while still pleasing their constituencies or agencies.

As discussed earlier, because of its dispersion, a virtual team could benefit from having a leader. Those benefits include the process of building trust [25], fostering role clarity, creating clear structure, and enhancing communication effectiveness [26]. Our study, therefore, tested two different leadership structures to see their effectiveness in the distributed environment. There are many ways to classify leadership, e.g., in terms of styles such as transformational vs. transactional [27] or technical, charismatic, caring-personal, and peer oriented [28]. In this study, we focused on what we call leadership structures rather than style, and examined the two structures of assigned versus shared leadership. In a virtual environment, observation of assigned vs. shared leadership should be easier than observing style characteristics. But an even more important reason for this choice was that we believe it represents a base-line starting point. For this study the participant playing the role of government official was chosen as the leader of the team in the assigned leadership condition. To eliminate potential confounding from gender differences, the government official role in each team was played by a male participant.

4.4 Technology and Tools

As noted previously, Groove was chosen as the platform for this study. This peer-to-peer (P2P) based technology has several advantages compared to a client-server system. While a client-server system would store data in a central location, in a peer-to-peer system every peer or node acts as both client and server and provides part of the overall information available from the system [29]. A synchronization process becomes an important part of P2P technology to keep information for every team member up-to-date. In this study, we encountered several problems related to the synchronization process. Two main problems were: (1) the Groove Instant Message function was not synchronized correctly during this process, so that several members of the research team could not receive messages for certain periods of time; and (2) the synchronization process took a long time to finish.

Once the platform was chosen, collaboration tools or process objects were integrated into Groove, since no such tools exist in this technology. Although process objects have been proved to be helpful in guiding face-to-face teams in doing collaboration [30], their deployment in virtual environments was still rare. Little knowledge existed on how these process objects should be adopted to match virtual environments and to be presented to a virtual team. The newness of process objects to most of the participants could create confusion about the tools that in turn could cause them to skip the use of the tools. For these reasons, we provided teams with only a limited number of process objects. Six process objects, each supporting one pattern of collaboration, were integrated into Groove. The patterns of collaboration are: (1) Diverge - *Move from having fewer concepts to having more concepts*; (2) Clarify - *Move from less to more shared meaning for the concept(s) under consideration*; (3) Reduce - *Move from having many concepts to a focus on fewer concepts deemed worthy of further attention*; (4) Organize - *Move from less to more understanding of the relationships among concepts*; (5) Evaluate - *Move from less to more understanding of the utility or priority of concepts toward goal attainment*; (6) Build consensus - *Move from having more disagreement to having less disagreement on courses of action* [31]. Each of the patterns was represented by a process object with a unique name. To educate participants in how to use the process objects, a brief description of each of the process objects was provided. The descriptions included the purpose of the specific object in the form of "if … then …" sentences. A brief example of how to use each object was also provided.

4.5 Data Collected

Shared understanding and satisfaction were recorded using a post-session questionnaire that asked participants about their demographic information, perceived shared understanding, perceived satisfaction, performance of their teammates, and feedback on how to improve this study. Additionally, a transcript of each team's communication via Chat on the Groove workspace was also recorded, for later use in analyzing how the leadership role was performed in each of the teams. Workspaces of each team were saved for analyzing how the team utilized the process objects provided. Message exchanges between team members and researchers were also recorded to analyze concerns raised by participants throughout the study. Team deliverables were saved for analyzing team performance in carrying out the task. Table 1 shows statistics of the data collected during the study:

Table 1. Statistics of teams and team members

#Participants	
Registered	70 participants
Joined	34 participants
# teams	14
# teams with deliverables	
with assigned leadership	5
with shared leadership	3
# teams using chat to communicate	
with assigned leadership	3
with shared leadership	1
# teams utilizing process objects	
with assigned leadership	4
with shared leadership	2
# teams utilizing meet and greet	
with assigned leadership	6
with shared leadership	7
# teams with 3 or more members	6
# teams with fewer than 3 members	8

The data shows that six of the teams tried to utilize process objects as collaboration tools, although we could still argue whether they used the tools correctly or not. The process object for the diverge collaboration pattern, called LeafHopper, was used by every team that used process objects. However, at this initial study, we did not collect data from participants about their attitude toward process objects and whether those process objects helped them in performing their task. Based on the data, we found that six out of eight teams with deliverables did utilize the process objects. Further investigation is still needed to determine the specific value of process objects for virtual teams. At this stage of the research, it is also unclear whether the leader role in each team was played correctly by either the appointed leader or the team members in the case of shared leadership. The fact that the majority of registered participants did not join their team at all raised questions about the challenges of performing distributed virtual team research. Therefore, next we discuss and identify some of the barriers in performing this type of research based on participants' feedbacks and our own self-reflection in administering the study.

5 Challenges in Distributed Collaboration Research

Based on qualitative and quantitative analysis of collected data and exchanged messages between researchers and participants, we can establish several reasons why available tools were not used and why the participation rate in this study was below 50%. We categorize those reasons into the two main categories of technical and environmental challenges. Technical issues are issues related to a technological problem or problem in using the technology, while environmental issues are issues related to participants' situation at the time of the study.

5.1 Participants' Concerns

Qualitative analysis of participant comments and exchanged messages revealed some of the causes of low participation. An analysis of exchanged messages shows that those messages can be categorized into three categories: (1) task related; (2) team related; and (3) technical related. The task related issues refer to participants' messages discussing the task, including but not limited to deadlines and meeting appointments, while the technical related issues refer to messages reporting about problems in using the technology, e.g., inability to see other team members. The team issues refer to messages complaining about team work or other team members, e.g., no other member joined the team. Table 2 shows a content analysis of exchanged messages:

Table 2. Statistics of messages based on their content

Issue addressed	Message received	Percentage
Task	19	40.4%
Team	15	31.9%
Technical	13	27.6%

A high percentage of task-related messages was a good sign, since it could be an indication that teams were working on the task as they were supposed to do. However, a high percentage of team-related and technical-related issues indicates that teams might have had problems in performing their task. A detailed look at these messages revealed that most of the time team members were concerned with their teammates not joining the team. In such situations, members would ask for guidance from the researchers in how to proceed with incomplete teams. Although a complete team would be an ideal condition for the researchers, they also needed to have an instruction or idea how to proceed in such case. Not having a clue how to proceed would frustrate members who had already joined the team. This comment from one participant mirrored his frustration with this situation:

"Make sure the people who sign up for it actually want to do it. When my teammates didn't log in, I was more than a little frustrated."

This frustration could be one of the reasons why participants only showed a mediocre satisfaction level at the end of the study. Table 3 shows the means of satisfaction with the process and satisfaction with the outcome for each treatment condition, where a score of 1 means less satisfied and a score of 7 means more satisfied. Participants seem to prefer clear instructions on how to proceed that are more likely to be associated with the assigned leadership condition.

Table 3. Means of satisfaction scales by leadership condition

Construct	Assigned leadership	Shared leadership
Satisfaction with Process	3.08	2.60
Satisfaction with Outcome	3.43	2.40

5.2 Technical Barriers

As Dubé and Paré [9] noted, an essential characteristic of a virtual team is their degree of reliance on information and communication technology (ICT). The teams in our study had a high degree of reliance on technology, since members were geographically dispersed. Therefore, a disruption of technology availability would likely lead to a breakdown of team functionality. Technical issues were identified by a number of participants as the source of problems in engaging in their collaborative work. Technical issues could rise from technology malfunction or from participants' inability to use or navigate the technology itself. The following messages from participants indicate their perceptions of technical problems:

"I have clicked on the invitation grf file and accepted, why isn't it appearing in the workspace tab of the browser? What is it doing. I don't seem to be adding a workspace. I created one called project relief but I was just messing around."

"Hey all ... sorry it took me so long to get added on to Groove. The first download I was sent would not connect me for some reason! So ... if someone will fill me in on any decisions that are being made that would be great. By the way I am the Aid Organization Coordinator."

The problem with the technology was also reflected by another participant during the post-session questionnaire. This person's comment showed a high level of frustration due to problems with the technology:

"I was unable to join the workspace even after troubleshooting with the VTCooordinator for several hours. My time was wasted in researching the project as well as trying to get into the workspace".

"I'm extremely sorry for the inconvenience, but I'm unable to participate in this project due to computer difficulties. I thought it was working alright, but something went wrong and I can't find the problem. Very sorry for the inconvenience".

It is difficult to get the exact numbers of people who chose not to participate due to technical issues, since only those who contacted the researchers and complained about their problems could be identified as having a technical problem. Furthermore, it was also difficult to verify the complaints of those who did contact the researchers. However, we did provide them with a hotline where they could report a problem and ask for advices from the research team. We set up a virtual helpdesk that was staffed between 7:00 am – 11:00 pm throughout the study period to respond immediately to participants' concerns. All concerns or questions were recorded into a helpdesk log that could be used as sources for answering similar questions from other participants. This concept of a virtual helpdesk proved to be useful in conducting this type of research.

5.3 Environmental Barriers

Working in distributed environments has become a challenge, especially for those who have not had experience working in such settings. As some participants expressed in the post-session questionnaire:

> *"I didn't like not being able to meet face to face"*
> *"I really would never want to work with Groove or a interactive (non face-to-face) program again. I feel like everything would have got accomplished a lot better with personal meetings. …"*

This could be seen as a support for Sarker and Sahay's [15] assertion that initial contact in a virtual team will not instantly result in collaboration. Some of the teams simply failed to reach the collaboration phase. The probability to fail for a virtual team seems to be higher if the leadership role is not filled. Especially in the case of assigned leadership, a team leader should guide team members in developing processes leading to expected outcomes. A team leader should act as a collaboration engineer who designs processes for the team and chooses appropriate thinkLets to be used. In the case of shared leadership, each member should take responsibility to move their team forward with collaboration. Some team members should take the lead in designing collaboration process for their team and they should make themselves familiar with available thinkLets. Distributed environments, however, have increased the challenges for doing so. Therefore, this challenge to jump start a collaboration in distributed environments should be taken into consideration when designing tools for virtual teams. While Appelman and van Driel [22] showed that a designed process could be executed successfully in a distributed setting, our study indicated that designing the process itself is a challenge for a virtual team.

Our approach of not providing training to participants regarding designing collaboration and utilizing collaborative tools has shed light to a level of awareness among participants about collaboration and process objects. The three types of thinkLet guidance provided to participants seemed insufficient in helping them understand the purpose and the usefulness of the tools. The following message reflected a participant's confusion on how to use existing tools:

"How do we actually use the tools such as Leaf Hopper? Do we need to start a new workspace or do we use the Project Relief Team 6 workspace? I don't understand how to open a new tool, or if I need to use the example shown in the Project Relief Team 6."

This reinforces the need for some level of training in introducing collaboration and process objects to virtual teams. One aspect of Collaboration Engineering principles is that thinkLets should be easy to use by anyone, without the intervention of a professional facilitator. Even though this may be the case in terms of the process that is described within the thinkLet, there still is a challenge in seamlessly presenting the process objects through technology.

Another barrier that is easily ignored by researchers is about the timing of conducting a virtual team study. The following comments from participants reflected their concerns regarding the timing of the study:

"The timing was horrible. It's the end of the semester and this was just adding fuel to the fire."
"These wasn't a ton of time to get work done. The project was given during a pretty hard time of the year to get things done."

The difficulty with the timing also led to several participants dropping out. One of them gave the following reason in his email as why he decided to drop out from the project:

"Very Sorry, but I have already made the decision and notified my professor. It will be hard to get everything else done that I have to accomplish this week, not to mention this project too if I took this on. I just can't handle the additional tasks. Thanks once again for the opportunity."

The message shows that timing plays a significant role in the participation rate of distributed virtual collaboration teams. Although the research team had estimated that in average participants would only need to spend 3-4 hours in this project, participants still perceived this project as time consuming and taking too much of their precious time. This non participation issue can be explained by rational choice model [32]. Based on this model, an economically rational actor would try maximizing his benefits from any activity, while minimizing his costs. Therefore, if participants perceived that the cost for participating in this project was higher than the perceived benefits, then they would be more likely to drop out of the project. To overcome this problem, researchers need to think about how to increase the perceived benefits of this type of project, while at the same time try to lower the perceived costs of involvement. The following table shows several ways to increase perceived benefits and to lower perceived costs of participations in distributed virtual team collaboration. These guidelines are stated in the context of a research project in a student setting, but they translate reasonably well to field settings.

Table 4. Ways to increase perceived benefits and lower perceived costs

Increasing perceived benefits	Lowering perceived costs
Make the project a required part of the course so that it is integrated with the regular activities of the course.	Time the project in balance with other activities occurring in the course. Manage expectations.
Emphasize potential achievement for participants.	Provide time for participants to learn about the technology but also about the interplay of the technology with the process.
Offer a reward for excellent work, within the guidelines and requirements of Institutional Review Boards.	Provide clear task instructions but also clear process instructions, in terms of how to proceed under different circumstances, e.g., lack of participation by some members.

Another problem was that team members joined their team in the last stage of the study. Since there was no penalty or cost for coming late to the teams, some of the participants maximized their benefits by participating only in the late stage of the project. This situation created a problem for researchers to make sense of shared understanding data collected at the end of the study, since there was no meaningful development of shared understanding in such teams. To address this issue, a strict rule is needed such as awarding credit only to those who fully participate from the beginning to the end of the project. Additionally, asking teams for temporary deliverables in the middle of the project would help in boosting team works and preventing last minutes only participations.

6 Conclusion

We have presented a discussion of the technical and environmental challenges of conducting research on Collaboration Engineering in distributed teams. Prior research on Collaboration Engineering has been done mostly using GroupSystems technology [33], [34], [35]. Our study is new in that we used Groove as a platform for collaboration. We have shown that process objects or thinkLets can be implemented in this technology, which suggests its adaptability and usefulness for collaboration. While research in distributed virtual collaboration is important, our initial study indicated that it is also challenging. High commitment from participants is required and unpredictable technological problems can lead to non-participation. We saw a high degree of probability that a team will not reach the collaboration phase at all and there can be a dependency on the team leader or members' initiative to design the collaboration process. Furthermore, the newness of collaboration tools or process objects can hamper participants from using those tools correctly. As our study indicated, some level of training for team leaders and/or members might be needed to make them familiar with collaboration tools in terms of process objects. At the same time, appropriate translation of process objects for their use in virtual environments is still needed in order to ensure that each process object is applied correctly and brings the intended results. Our effort to provide guidance for thinkLet use failed to increase awareness among most of the participants regarding the usefulness of thinkLets. Therefore, future studies should help in addressing the issue of effective guidance in virtual environments.

The limitations of the current study include a small numbers of participants and the short period of the study. However, we expect through this initial study to be able to record and disseminate best practices in how to conduct this type of study. Based on the current study, we offer the following recommendations for future research in Collaboration Engineering for distributed teams:

1. Provide some level of training for designing collaboration processes and using process objects for participants in virtual environment.
2. Provide enough time for the team to move from initial contact to collaboration, since teams need to go through several development phases.
3. Ask for interim deliverables in order to study how shared understanding is emerging.
4. Find the best way to integrate collaboration technology with process objects, in order to lower the perceived barriers among team members to use those tools.
5. Know the technology platform and its potential problems, so that technical assistance can be provided to participants immediately.
6. Provide warm-up time for participants to learn more about the technology used, existing tools, and their teammates, before starting with data collection.
7. Schedule the project with an eye to balancing other commitments, while managing expectations for engagement with the virtual experience.
8. Set a strategy to increase perceived benefits of involvement in the project among participants, while at the same time lowering perceived costs of involvement.
9. Be clear on rewards for participation in the study.

Several of the recommendations reinforce what we know from the domain of traditional teams and projects. The key issue in this study has been the question of how well the principles and practices of Collaboration Engineering translate to distributed environments, including the ease with which we can develop and implement a flexible infrastructure for the use of a broad range of process objects. This study shows that it is possible to use a peer-to-peer application as the foundation for creating a collaboration environment that can then be used in different ways by different teams. However, the study has also reinforced that distributed teams need more work than we expected in order to get up to speed with being able to use and adapt processes for themselves. This initial test of Collaboration Engineering, in this one specific environment, shows that there is interesting work yet to be done on the best ways to integrate collaboration tools with processes and leadership, in order to help virtual teams perform rapidly and effectively across a wide variety of tasks.

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[1]Detailed descriptions of the thinkLets and the post-session questionnaire are available by request from the first author.