Learning to Work in Partially Distributed Teams: An Analysis of Emergent Communication Structures and Technology Appropriation

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Abstract

A partially distributed team is a virtual team, in which two or more co-located subteams use communication technology to collaborate across distance. Due to factors such as globalization and mergers, an increasing number of IT projects are conducted in partially distributed teams (PDTs). However, students lack experience in how to work effectively in such situations. This field study involved more than 500 students from seven U.S. and seven international universities, working together in PDTs. Through the lens of the Fit-Appropriation Model, quantitative and qualitative analyses were conducted regarding three emergent communication structures (hub-and-spoke, moderate network, and high-network) Findings indicate significant differences in terms of communication technology usage and self-reported learning outcomes. The communication structures differed along two appropriation dimensions -- inclusivity and adaptiveness -- which mediated learning outcomes.

1. Introduction

Partially distributed teams (PDTs) consist of two or more subteams that are separated geographically. In a PDT, the members of any given subteam are co-located, (e.g., they may meet face-to-face, but they collaborate remotely with members of other subteams using information and communication technology). PDTs, are an increasingly normal mode of operation in a variety of domains including IT, business, and disaster management [1]. Often the geographic distance separating subteams spans multiple time zones and countries, as in the case of global software development PDTs [2], [3], [4], [5], [6], [7].

Thus, an essential skill for the IT professional is knowing how to work effectively in such teams. Given that employers want IT graduates who are “job ready,” educators are called upon to “ease the transition from academia to the business world by teaching students to work in teams and providing significant project experiences” [8]. To this end, we have conducted a series of field studies, over several years, designed to provide students with deep learning experiences with respect to PDTs [9].

This paper presents findings from the most recent field study involving more than 500 students from seven U.S. and seven international universities. We explore findings related to three emergent team communication structures and the appropriation of technology by these teams, with respect to learning outcomes. We do this through the lens of the Fit-Appropriation Model [10] [11]. Following background on the PDT project, we present the conceptual model, describe the methods and discuss quantitative and qualitative findings. We end with conclusions and plans for future research.

2. Preparing Students to work in PDTs

2.1 Pedagogical Approach

Our pedagogical approach incorporates elements of Project-Based Learning, Team-Based Learning, and collaborative approaches to online learning; it thus extends the transformative changes in higher education that have become increasingly widespread in recent years. Project Based Learning (PBL) is “a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks” [12]. It emphasizes authentic “real world” tasks that incorporate the project management skills so valued by today’s global industries [13]. Team-Based Learning (TBL) emphasizes team development and has been shown to enhance motivation, long-term retention, critical thinking, and communication skills [14]. It is aimed at developing high-performing teams of learners; it seeks to transform groups into teams...
characterized by members that exhibit high effort and commitment and are thus “capable of solving problems that are beyond the capability of even their most talented members” [15]. By keeping groups intact through a series of well-planned activities designed around a three-phase sequence of preparation, application, and assessment, TBL has been shown to enhance learning achievement in traditional face-to-face (FtF) classroom settings [16]; FtF classes supported by a mix of synchronous and asynchronous communication media [17]; and strictly online learning contexts [18], [19], [20].

While many technology students have worked on team projects, our prior work with student PDTs revealed that few, if any, have experience collaborating in distributed teams in general, and in PDTs specifically [9].

2.2 Training for distance work

Numerous studies suggest that virtual team members could benefit from training on the intricacies of working in a distributed context. For example, [22] recommends training for virtual team leaders; [23] recommends educating virtual team members about the pitfalls of the failure to share situational information and the tendency to make (incorrect) assumptions about remote partners and locations. Training on diversity awareness in distributed teams is recommended by [24], [25] notes that organizations today do not adequately train members in virtual team work. The need to prepare students to be effective members of virtual teams is recognized, but to date, little headway has been made beyond introducing such projects into the classroom setting (see [1], [26], [27] for recent case studies).

In an attempt to address this shortcoming, we developed a four-week project involving student PDTs. Based on empirical data gathered from initial semesters, a series of three training modules were designed to scaffold students’ PDT collaboration behaviors; these training modules were interwoven into a four-week PDT project (see Methods). Findings indicate that, with respect to their distant subteam, students that completed the training modules reported significantly higher levels of team development (i.e., higher trust, shared team identity, awareness, coordination, perceived competence and less conflict) compared to students who did not complete the training modules. Furthermore, students with training reported significantly higher levels of perceived team performance compared to their without-training counterparts. Details of the training modules, our action research approach, and of these impacts on students are presented in a recent paper [9].

3. Framework and Conceptual Model

During prior PDT field studies, we observed that teams communicated using one of three emergent structures. Some teams adhered to a hub-and-spoke communication structure, with interaction occurring primarily between the two subteam leaders who then disseminated information to their respective subteams. The other two structures were variations of a network. In the moderate-network structure, some members (less than a majority) within each subteam communicated with their distant counterparts. In the high-network structure, most subteam members (a majority) communicated with distant subteam members.

We explore these emergent communication structures through the lens of the Fit- Appropriation Model (FAM) [28] [11]. FAM proposes that team performance is impacted by both task-technology fit (TTF) and the appropriation of technology. TTF refers to the extent that the functionality of a technology complements task requirements and the people performing the task [29]. Theories encompassing TTF (e.g. Media Synchronicity Theory, [30]) contend that a good fit between the task, the technology, and the associated team can result in enhanced performance [29], [31].

Appropriation of technology – that is, how teams use features of the technology – provides a different perspective on influencers of performance. Appropriation is a focal component of adaptive structuration theory (AST) [32], [33], [34]. AST posits that various sources (e.g., technology, task, the team’s internal system) provide structures that impact team interaction processes, which in turn, affect team outcomes [33]. A technology’s structures refer to the capabilities inherent in the technology and can be described by the functionality embodied by the technology. Additional sources of structure are provided by the team’s task (i.e., the task requirements) as well as internal characteristics of the team, such as its interaction style and leadership.

By integrating TTF and AST, FAM argues that a better understanding is provided regarding how technology use impacts team performance. FAM proponents espouse, “TTF is a necessary but not sufficient condition to improve performance...That is, task-technology fit affects performance, as moderated by appropriation... Appropriation itself is affected by the fit itself…” [28].

Conceptual Model

The conceptual model for this study, depicted in Figure 1, is based on the FAM theoretical framework. Structures that impact PDT interaction include communication technology, tasks, and team leadership.
PDTs use a combination of asynchronous and synchronous communication technology to collaborate across distance. Subteams work together to accomplish two types of tasks: (1) determining high-level functional requirements for an emergency preparedness information system and (2) training tasks designed to teach students about collaborating in PDTs.

Teams were newly formed, so they did not have pre-existing norms or an interaction style to provide structure. However, all teams were configured with two subteams and each subteam had a leader.

The task-technology fit in conjunction with the leadership style within a given team influences team interaction in terms of technology appropriation and emergent communication structures. Technology appropriation – that is, the degree to which a given technology is used and the manner in which it is used – co-evolve with team communication structures. These interact and impact student learning in terms of the domain of emergency preparedness, PDT learning, learning interest, and work satisfaction with the distant subteam. We explore these relationships in the remainder of this paper.

4. Method

Participants

Over 500 students participated in the study and were drawn from a diverse set of IT courses in seven US and seven international universities. The U.S. universities were: (1) Penn State University, (2) Jacksonville State University (AL), (3) North Carolina Agriculture & Technology State University (NC), (4) Rider University (NJ), (5) Miami University (OH), (6) St. Louis University (MO), and (7) University of Washington (WA). The international universities were: (1) Carlos de Madrid III University (Spain), (2) Hunan University (China), (3) Kaunas University of Technology (Lithuania), (4) Kiel University of Applied Sciences (Germany), (5) Tecnológico de Monterrey (Mexico), (6) Turku University of Applied Sciences, (7) Universidad Carlos III de Madrid (Spain).

Each of 54 teams consisted of two subteams. Each subteam was from a different university and consisted of about five students drawn from the same collocated class. Thus, members within a given subteam were able to meet face-to-face, however subteams within a given team were geographically distant from one another and had to collaborate using technology. Students were assigned to subteams and teams prior to the start of the project. Subteams were formed using one of two methods: (1) instructors put their students into subteams or (2) the first author randomly formed subteams within a given class. The first author formed teams using a quasi-random method. Two subteams were paired to form a team; each subteam was from a different university. In an effort to reduce coordination costs for the instructors, a rule of thumb was that an instructor’s class should not be paired with students from more than two other classes. However, this rule did not hold for instructors at the University of Washington or Penn State, due to relatively large class sizes.

Leaders

Prior studies of leadership in student PDTs indicate that a leadership structure with one leader per subteam may be the most natural fit [36]. Therefore, each subteam was required to select one subteam leader.
Leadership instructions regarding responsibilities were summarized in a document that team members were required to read. These responsibilities were based upon research on leadership roles [35], [36], [37]. Leadership roles included coordinating with the other subteam leader and within the leader’s own subteam, mentoring own subteam members, and taking charge of completion of activities and deliverables.

Project Tasks and Procedures

The PDT project was designed to be appropriate for students from different geographic regions and cultures.

Throughout the four-week project period, teams completed weekly activities and deliverables pertaining to the two main areas (emergency preparedness and PDT collaboration training) (see Procedures). Regarding emergency preparedness, in weeks two-four, students worked on GRRR (Grassroots Regional Resource Repository); they did not work on GRRR during the first week. Regarding GRRR, students analyzed and presented the functionality for a self-help regional emergency preparedness information system. The purpose of the system was to provide a way for those living in a given geographic region (e.g., Costa Rica) to locate and manage the resources of that region (e.g., skilled labor, equipment, supplies) so that the resources can be deployed efficiently and effectively in a disaster. Specifically, in week two, they brainstormed about the functions to be included in GRRR, and prepared an outline of the functionality; in week three, they drafted an outline of the functions, and in week four, they completed a written report describing the GRRR functions along with screen shots of the user interface.

Regarding PDT training, students completed three modules. The goal of Module 1, completed in the first week of the project, was to get teams off to a good start. Teams completed activities designed to clarify team expectations and responsibilities, and to raise awareness of issues of working in PDTs. They drafted a contract that includes sections on how they will communicate (e.g., technology to be used, frequency of communication, acceptable timeframe for feedback), the frequency of team meetings, project management and procedures for addressing conflict between subteams. They also selected subteam leaders.

The goal of Module 2, during the second week, was to help teams form a whole-team identity, as opposed to separate subteam identities. Module 2 included a team building exercise in which students interviewed members of their counterpart subteam and created a team page of member biographies and team attributes.

The goal of Module 3, in the third week, was to establish a positive team trajectory. The team assessment activity was designed to help students assess their team interaction and performance during the first half of the project and to reach agreement on an action plan for improvement. Teams were not assigned any team building activities in the fourth week.

To foster motivation, the project constituted a substantial portion of the course grade (generally about 20%). In terms of grading deliverables, rubrics established from prior runs of the project were utilized. Points were awarded for both successful completion of the activity processes as well as the quality of the deliverables.

Communication Media

To support team collaboration, we developed a custom system using Drupal, an open source web-based communication and content management system. Additional functionality to support team activities was added via third-party plug-ins. Basic features included a threaded discussion board and file repository. The asynchronous system did not allow for the open-editing often associated with wikis. Each team had its own private space on the system. An important reason for using this centralized open-source approach was to meet the access needs of international students; we could not assume that they would have funding or personnel to purchase, install, or maintain relevant software. All project content materials were posted on the PDT collaboration system.

Data sources and instruments

At the conclusion of the PDT project, a post survey was administered to participants. In order to better explore the results of different communication structures that the teams employed, a question asking students to select how their between-subteam communication occurred most often was added to the previously developed post survey [9]. Students were given the choice between three communication structures: (1) only through subteam leaders (hub-spoke), (2) between some members from each subteam (moderate-network), or (3) between most members from each subteam (high-network).

Technology usage was measured subjectively via a question on the post survey, where respondents rated their usage of 13 technologies including the PDT system, email, instant messaging, Internet phone, etc., (see Appendix A for a complete list).

Outcomes related to student learning were measured subjectively via the post survey in terms of three primary dimensions: learning to work in partially distributed teams, interest in the PDT project, and satisfaction in working with distant subteams. Scale items for these constructs are presented in Appendix B.
Additionally, at the end of each week participants completed personal reflections, in which they were given the opportunity to describe their teaming experiences during that week of the project. Results of the team assessment activity, in Module 3, were also used in the qualitative analysis.

5. Analysis

5.1 Quantitative Analysis

Post survey responses were received from 381 participants for a response rate of 73%. Reliability was acceptable across all scales with a Cronbach’s alpha coefficient of .70 or higher.

An ANOVA was conducted to explore the relationships between team communication structure (predictor variable) and technology use and learning outcomes (dependent variables). In terms of communication structure, 134 students indicated that their team utilized a hub-and-spoke structure, 183 indicated a moderate-network and 64 indicated a high-network.

The descriptive results for the dependent variables are presented in Table 1. Given a seven-item response scale for all dependent variables, there is a relatively large degree of dispersion, especially for PDT system usage and instant messaging. Thus, students within a given communication structure exhibited rather wide-spread variability in their ratings of the dependent variables.

Significance levels of pairwise comparisons of communication structures are presented in Table 2. For technology usage, only data for significant results are shown; significant differences were found regarding the PDT system, instant messaging, and Internet phone. Across communication structures for these three technologies, the PDT system was rated highest in terms of usage and Internet phone the lowest. The contrast between hub-and-speak, moderate-network, and high-network communication structures revealed increased ratings for all three variables, as shown in Table 1. The spread between high-network and hub-and-speak structures was the greatest, with significant differences across all three technologies, as shown in Table 2. Although there

### Table 1. Scale Means and Standard Deviations

<table>
<thead>
<tr>
<th>Commun. Structure</th>
<th>Technology Usage (7 pt. scale)</th>
<th>Learning (7 pt. scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PDT system</td>
<td>Internet Phone</td>
</tr>
<tr>
<td>Hub-spoke</td>
<td>3.98 (1.97)</td>
<td>4.06 (1.58)</td>
</tr>
<tr>
<td></td>
<td>Instant Msg.</td>
<td>2.93 (2.18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.46 (1.27)</td>
</tr>
<tr>
<td></td>
<td>EP Learning</td>
<td>4.93 (1.69)</td>
</tr>
<tr>
<td></td>
<td>Project Interest</td>
<td>4.26 (1.87)</td>
</tr>
<tr>
<td></td>
<td>Work Satisfaction</td>
<td>4.72 (1.96)</td>
</tr>
<tr>
<td>Moderate network</td>
<td>4.52 (2.51)</td>
<td>4.43 (1.44)</td>
</tr>
<tr>
<td></td>
<td>Instant Msg.</td>
<td>3.30 (2.31)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.53 (1.40)</td>
</tr>
<tr>
<td></td>
<td>EP Learning</td>
<td>5.46 (1.38)</td>
</tr>
<tr>
<td></td>
<td>Project Interest</td>
<td>4.91 (1.73)</td>
</tr>
<tr>
<td></td>
<td>Work Satisfaction</td>
<td>5.16 (1.81)</td>
</tr>
<tr>
<td>High network</td>
<td>5.27 (2.03)</td>
<td>4.64 (1.55)</td>
</tr>
<tr>
<td></td>
<td>Instant Msg.</td>
<td>4.25 (2.49)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.91 (1.82)</td>
</tr>
<tr>
<td></td>
<td>EP Learning</td>
<td>5.98 (1.17)</td>
</tr>
<tr>
<td></td>
<td>Project Interest</td>
<td>5.20 (1.58)</td>
</tr>
<tr>
<td></td>
<td>Work Satisfaction</td>
<td>5.69 (1.57)</td>
</tr>
</tbody>
</table>

### Table 2. Significance levels of pairwise comparisons of communication structures

<table>
<thead>
<tr>
<th>Commun. Structure</th>
<th>Technology Usage</th>
<th>Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PDT system</td>
<td>EP Learning</td>
</tr>
<tr>
<td>Hub-spoke vs. Moderate</td>
<td>.021</td>
<td>.033</td>
</tr>
<tr>
<td>Hub-spoke vs. High</td>
<td>.000</td>
<td>.013</td>
</tr>
<tr>
<td>Moderate vs. High</td>
<td>.011</td>
<td>.349</td>
</tr>
</tbody>
</table>

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was less spread between moderate- and high-network structures, there were significant differences for both the PDT system and instant messaging. Hub-and-spoke and moderate-network structures showed significant differences for PDT system usage. These data suggest that technology usage regarding the PDT system, instant messaging, and Internet phone are tied to the communication structures adopted for between-subteam communication.

Regarding learning, across the three communication structures, PDT learning was rated highest followed by satisfaction working with the distant subteam; project interest ranked third with emergency preparedness (EP) learning ranked fourth. All rankings were above the scale midpoint of 4.0. Again the contrast between hub-and-spoke, moderate-network, and high-network communication structures revealed increased ratings for all learning variables. The spread between high-network and hub-and-spoke structures was the greatest, with significant differences across all variables. Although there was less spread between hub-and-spoke and moderate-network, there were significant differences across all variables. Again, the contrast between moderate- and high-network was less broad-spread, with significant differences for PDT learning and satisfaction working with the distant subteam. Similar to technology usage, these data suggest that perceptions of learning are also tied to the between-subteam communication structures.

### 5.2 Qualitative Analysis

To further explore the quantitative findings, a qualitative analysis of the weekly personal reflections and Team Assessment outcomes was conducted on a subset of teams. To select teams, first a pool of teams was formed consisting of those teams with strong agreement among members on type of communication structure (i.e., the majority of team members selected the same response for the communication structure question on the post survey). From this pool, teams were segregated according to the three types of communication structures. Then, response rates across team member personal reflections were reviewed. Based on this data, we selected international teams (i.e., each subteam from a different country) with the highest and most consistent number of member personal reflections across the four-week project period. This resulted in the selection of six teams from the hub-and-spoke and moderate-network team structures, and three teams from the high-network structure, as indicated in Table 3. Following is a summary of the qualitative findings for each communication structure.

#### Table 3. Teams used in the Qualitative Analysis

<table>
<thead>
<tr>
<th>Communication Structure</th>
<th>Teams</th>
</tr>
</thead>
<tbody>
<tr>
<td>hub-and-spoke</td>
<td>10, 18, 21, 35, 39, 44</td>
</tr>
<tr>
<td>moderate-network</td>
<td>19, 25, 38, 41, 46, 47</td>
</tr>
<tr>
<td>high-network</td>
<td>12, 15, 16</td>
</tr>
</tbody>
</table>

#### High-network Teams

At the project inception, the PDT team discussion forum was a valuable resource for high-network teams to establish contact with distant members. As the project progressed, the forum was used less as team members had more success communicating via e-mail.

From the beginning, high-network teams frequently used chat to socialize and conduct team meetings. For these teams, developing such a connected social network took time. As noted by one team member, “Our first meeting took far too long (7 hours!, on and off) but part of that time was spent getting to know each other. Hopefully we will find ways to work more efficiently from now on” (Team 12). In mid-project self-evaluations (conducted during Module 3), two teams noted that meetings had taken up too much of their time, and in the same week a member reflected, “Perhaps we should try to involve fewer people than everyone on the document editing online” (Team 12).

All three of the high-network teams also reported using Skype’s Internet phone feature to communicate between subteams. As noted by a subteam leader, “I really like how we can all meet online as a team. It’s very interesting to talk about various things on Skype with [other subteam]” (Team 16).

High-network teams saw communication as a goal in itself, distinct from producing quality work. This is illustrated by a subteam leader who indicated that although he was satisfied with the team’s work products, “I would like to see more participation and collaboration on some issues” (Team 16).

The high-network teams considered it important to share opinions and discuss topics with the entire team, not just within subteams. One subteam leader reflected, “Our team works in friendly way, we do all tasks together and we able to come to our united opinion. Sometimes our opinions are different, but we discuss till we come to united opinion” (Team 15).

However, by the project midpoint, the teams noted that their commitment to increased (synchronous) communication had a cost in terms of efficiency. During the second half of the project, the high-network teams adjusted their work practices by...
reducing their use of synchronous media. In the third and fourth week reflections, the high-network teams reported that work became smoother and more efficient. For team 12, this occurred even while a subteam leader had a week-long absence: “Looking back at this week, the work got done and I didn’t receive any ‘panicky’ email so that signifies that our team is working properly and I as a sub-team leader only act as guidance” (Team 12).

**Moderate-network Teams**

Moderate-network teams shifted quickly from using the PDT forum for initial contact to primarily using e-mail for asynchronous communication. As one member commented, “We’ve been doing our job by communicating via e-mail…” (Team 46). All members of one team had a common platform for email; a member noted that “Having a mailing list and everyone with a gmail account is a plus” (Team 47).

Moderate-network teams used chat mainly as a supplementary tool, to clarify points already made via email. Some held meetings using chat; unlike the high-network teams, there were no complaints about meetings lasting too long because of socializing. Still, moderate-network teams saw some of the same benefits from chat as high-network teams, as noted by one member: “Being in contact with the American subteam and chatting about the tasks is great and funny experience. I guess, that we now have built up a solid foundation of trust” (Team 38).

Overall, however, whereas high-network teams were “friendly” in their communications, moderate-network teams were “business-like.” Their primary focus was on completing the assignments; building camaraderie between subteams came second.

Perhaps as a consequence of this task focus, when a team encountered conflict stemming from dissenting opinions, a subteam leader commented, “In future we will want to come to an agreement within our sub-team before we will say our opinion to the American sub-team because we think, that this way will prevent unnecessary confusion by our American sub-team” (Team 38). In effect, the leader indicated a preference for efficiency over collaboration.

Throughout the project, one subteam leader reflected that increased communication would be beneficial to the team in general, and in the final reflection, commented “Communication was better this time, between subteam’s member and between all member of team 41.”

**Hub-and-spoke Teams**

Like network teams, hub-and-spoke teams established initial communication through the team discussion forums and then conducted asynchronous communication via e-mail. As noted by a team member, “Once someone on the other team made their introduction, we were able to proceed via e-mail, which was much faster” (Team 44). However, unlike networked teams, hub-and-spoke teams did not use e-mail in a collaborative manner. As commented by a team member, “…I don’t email the other team members as frequently, but that’s not detrimental to our team cohesiveness because Alfred acts as our central command” (Team 21).

From the project inception, in stark contrast to the high-network teams, hub-and-spoke teams had issues with communication. As the project progressed, they increasingly used leader-to-leader e-mail for between-subteam communication. For example, hub-and-spoke teams were unsuccessful using chat, with most giving up after the first week. One team did manage to hold a team chat session, but succeeded in arranging it only in the last week of the project. A member commented, “It went very well, in terms of touching base and getting an idea of what we needed to do” (Team 21).

Leaders in hub-and-spoke teams viewed themselves more as organizers and subteam representatives compared to network leaders who acted more as facilitators of communication between subteams. A leader reflects, “As leader I’m coordinating my subteam’s work, I’m trying to combine our decisions with subteam from [large US university]” (Team 10).

Some teams did adjust their communication practices. As noted previously, one team used chat to conduct meetings in the last week. However, not all teams were successful. For example, one team identified in the mid-project assessment that it was not building enough camaraderie and suggested the use of real-time communication to help improve the situation. However, this idea was never implemented, as indicated by the final reflection on one member: “I felt that the project was very short, and we did not really get to know the other subteam-members fully. I would say that the leaders did most of all work. I think we should have communicated more with the other subteam” (Team 39).

**6. Summary, Discussion and Conclusions**

To summarize, high-network teams used synchronous technologies heavily during the first-half of the project. While this proved to be a poor fit regarding tasks such as document editing, it was quite beneficial in establishing socio-emotional
connectedness between subteams. Communication between subteams, and indeed all members, was as important as producing quality deliverables. These dual goals promoted an atmosphere of inclusiveness – both in terms of technology use and team communication structures, where opinions were shared and topics were discussed with the entire team. The tone of communication exchanges was personal, friendly and informal. As the project moved into the second half and team relationships were established, these teams adapted their appropriation of technology to increase efficiency.

Moderate-network teams used synchronous communication to supplement asynchronous communication. Building camaraderie between subteams was secondary behind a focus on completing task deliverables; the tone of team communications was business-like. There was some evidence of a move to use more chat as the project progressed, however, since there was more of a balance in terms of using both asynchronous and synchronous technologies initially, and arguably better task-technology fit, changes in appropriation were less apparent compared to high-network teams.

Hub-and-spoke teams experienced between-subteam communication problems. These teams used asynchronous communication predominantly. Furthermore, between-subteam communication was funneled through the subteam leaders who acted as gatekeepers. Thus, there was limited direct interaction between members of distant subteams. Hub-and-spoke teams exhibited little change in their appropriation of technology during the second half of the project. Thus, whereas high-network teams can be characterized as adaptive and inclusive with respect to their appropriation of technology, hub-and-spoke teams are best described as “sticky” and exclusive – how they started using technology is, fundamentally, how they ended -- using asynchronous technologies with leader-to-leader communication.

Subteam leaders played a crucial role in decisions regarding task-technology and appropriation. Network leaders promoted inclusiveness – in terms of media usage as well as establishing communication norms whereby members were encouraged and expected to participate, where divergent opinions were expressed and discussed. In particular, high-network leaders went beyond the leadership roles outlined in their instructions (coordinator, mentor, scheduler, etc.). Whereas leaders in hub-and-spoke teams focused on their coordination role, and in essence, acted as communication gate-keepers, networked leaders elevated communication to a team-level priority, and acted as communication czars.

**Impact on learning**

The analysis points to key differences between the three types of team communication structures. The teams varied along two appropriation dimensions: degree of adaptiveness (anchored by adaptive and sticky) and degree of inclusiveness (anchored by inclusive and exclusive), as shown in Figure 2. Appropriation in this sense refers not only to technology, but to team structures, such as leadership. Leaders were a critical influence on the placement of their teams within the three communication structures and along these dimensions.

![Figure 2. Appropriation Dimensions](image)

Members of high-network teams benefited from inclusiveness, both in communication processes and technologies appropriated to support these processes, and adapting technology appropriation and team processes as subteams learned to work with each other across distance. These teams ranked significantly higher across all learning scales compared to the exclusive/sticky hub-and-spoke teams and with regard to three out of four learning scales compared to the relatively more inclusive/adaptive moderately-networked teams (only learning pertaining to emergency planning was unaffected by moderate- vs. high-network communication structure).

The goal as we move forward with the PDT project is to increase learning. We are developing a communication training module that will focus on appropriation training [38] with respect to the adaptive and inclusive dimensions in Figure 2. Since leadership is an integral part of the communication structures that emerged, an expanded set of leadership responsibilities that include a focus on the appropriation dimensions will be developed. We intend to pilot test the communication and leadership training during Fall 2009.
7. Acknowledgments
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8. References


APPENDIX A: Technology use survey question
To what extent were the following means of communication used between subteams?

- PDT system
- Instant messaging
- E-mail
- Text messaging
- Facebook
- Phone (mobile or land-line)
- Internet phone (e.g. Skype)
- Face-to-face meetings
- FAX
- Video conferencing
- Teleconference calls
- Course management system
- External forums or bulletin boards
- Other (Please describe)

The media use response scales were 7-point, anchored with “never” and “to a great extent”.

APPENDIX B: Learning-related constructs and associated scale items

PDT learning (adapted from Hiltz 1988, 1994 & Alavi 1994)
Working on the PDT project:
- increased my ability to team with others across distance
- increased my skills at working in a distributed team
- gave me good hands-on experience at collaborating across distance
- provided me with a real-world perspective on distributed teams

Learning Interest in the project (adapted from Hiltz 1988, 1994 & Alavi 1994)
While working on the PDT project:
- I talked about the project with non-team members.
- I talked to friends about working with my distant team members.

Satisfaction working with other subteam (adapted from Fuller et al., 2006-7)
- I was satisfied with members of the other subteam.
- I was pleased with the way members of the other subteam and I worked together.
- I was very satisfied working with the other subteam.

The learning-related response scales were 7-point, anchored with “strongly disagree” and “strongly agree.”