New Methods for Studying Global Virtual Teams: Towards a Multi-Faceted Approach

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Abstract[1]

Virtual teams are increasingly global, creating challenges for communication and coordination due to greater distances, multiple time zones, and cultural differences. A longitudinal research program investigating communication and collaboration in globally distributed engineering design teams is described. Preliminary results illustrate the value of combining quantitative and qualitative sources of information on team communication, working patterns, and outcomes. Quantitative data includes communication logs, system usage data, and questionnaires. Qualitative data includes participant-observation, interviews, transcripts of team events, and incident reports. Findings focus on the appropriation of technology by teams, the "stickiness" of media usage patterns, the sometimes opposing effects of group technology on team perceptions and the impact of cultural and power issues on communication practices. Qualitative and quantitative data offer distinct, but complementary insights into team dynamics, supporting the view that understanding virtual team processes requires multi-faceted research approaches.

1. Introduction

The extensive literature on group work has concentrated predominantly on 'co-located' teams [25]. Organizations increasingly depend on virtual teams, in which interaction and collaboration takes place among geographically-distributed, and often culturally-disparate individuals. Often these teams are globally dispersed, following the patterns created by multinational firms, global alliances, and international trade. As a consequence, interest in how to improve collaboration in global virtual teams is growing [6, 9, 10]. Numerous practical questions face managers of such distributed teams, including: what modes of communication can and should be supplied, what types of computer-based coordination and support are needed, what project and information management approaches best enable groups to coordinate and manage interdependent work, how cultural boundaries can be crossed, how perceived power problems can be neutralized, and how group cohesion, motivation and morale can be sustained effectively.

Globally distributed teams are different from less widely distributed groups. Global teams are more likely to have members working in different cultural contexts, more likely to be zero history groups, and less likely to have opportunities for face-to-face interaction [8]. Such teams require different methods to create and maintain relationships.

Cultural disparity means that virtual team members must develop mutually acceptable norms for interaction. Additionally, the time zone differences typical among such teams makes coordination through real-time interactions more difficult to arrange, requiring more reliance on asynchronous modes of communication. This in turn increases the likelihood of problems related to information distribution and interpretation [3].

A growing body of research explores group dynamics in virtual teams, particularly within the context of computer-based communication and collaborative systems [3, 8, 15, 16, 17; 20, 21]. This emerging research

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area, however, raises new challenges for the research process. For example, many researchers rely on in-depth case studies of virtual teams as the source of data on group dynamics. Such case studies often rely on ethnographic methods. These require prolonged direct access to team members by researchers, debriefing of team members on the spot, and comparisons of contextualized knowledge across sites. We recognize that for many globally distributed teams, such access is too costly and difficult to obtain. Virtual team researchers must cope with the problem of how to study individuals and groups when researchers cannot be physically present at every location.

Such methodological issues deserve more attention. A clear trend in virtual team research is to use multi-method approaches, integrating data from a variety of sources [3, 8, 15]. This paper introduces a multi-faceted research model that acknowledges the complexity of researching distributed teams. The approach involves a team of distributed researchers, explores multiple virtual teams over time, and uses triangulation across a range of qualitative and quantitative sources of data to understand virtual team processes. We illustrate how such an approach provides new insights into virtual team processes, and helps avoid making flawed inferences based on partial views of teams' interactions.

2. Multi-method approach

Studying global virtual teams presents many new challenges for researchers, including: establishing multi-disciplinary research partnerships with universities abroad, finding research participants to work on virtual teams, coordinating research activities in multiple locations, and providing common communication and technological platforms across locations. In this section, we describe how we formed virtual teams, the cooperative arrangements that supported coordination of our research procedures, and our approach to providing a common technological platform for the groups. We then outline the specific types of data we collected.

2.1. Forming global virtual teams

An important tradeoff in this and other group research is the traditional tension between studying naturally occurring teams *in situ* vs. artificially constructed teams in laboratory settings [23]). Our compromise approach is to include artificially constructed teams of students, while attempting to create a realistic setting involving a long-term collaborative experience. In part, we relied on student teams for practical reasons, due to the difficulty of gaining long term access to globally distributed teams of professionals. We also wanted to test our ideas about the types of information and communication technology that could be used to support such teams, and therefore sought an approach that offered the researchers more control over the tools provided, in contexts where the consequences for failure were not severe.

2.1.1. The need for multi-disciplinary, trans-national partners. To study virtual teams, partnerships across disciplines are needed. ICT researchers emphasize the technological issues and the interaction between groups and technology. Organizational Anthropological researchers emphasize trans-cultural and power issues between groups as well as communications issues stemming from disparate cultural conventions concerning the use of technology. Dialogue among researchers is required to establish research practices that span the differences between empiricist and interpretive paradigms of knowledge production [1].

No single institution can easily form such global virtual teams - it usually requires global partnerships. Alliances between cooperating faculty at universities in different countries provide access to students from which teams can be constructed. Moreover, cooperating researchers can ensure that equivalent research procedures are followed in each place.[2]

In our desire for realism, we also forged partnerships with industry. Industrial partners provide realistic projects for the teams, giving them a sense that their efforts have a real client and a purpose.

2.1.2. The INTEnD consortium. To these ends, in the fall of 1997 we formed the International Networked Teams for Engineering Design (INTEnD) Consortium. Early discussions with potential industrial partners focused our attention on engineering design tasks. Due to the increasing shortage of engineers in many countries, our industry partners are seeking ways to rapidly form global design teams making use of engineering talent in distributed locations. The time-to-market pressures created by strong global and IT-based competition also spark an interest in improving coordination among distributed teams of engineering designers.

INTEnD was initiated by Michigan State University (MSU) as an open consortium of universities for the purposes of cooperating on the formation and study of global virtual teams. Participating universities in the past two years include Delft University of Technology in the Netherlands (TUD), St. Petersburg State Technical University in Russia (SPSTU), Universidad Carlos III in Madrid, Spain (UC3M), and Tsinghua University in

[2] Although Cramton (1997) demonstrates clearly the difficulties such loose consortia of academic researchers face in maintaining consistent contexts for global student teams.

Beijing, China (THU).

To date, virtual team formation and engineering design project management occurred as follows. One or more engineering faculty at each of the schools recruited students to work on virtual design teams. Throughout the project, engineering faculty worked with the students intensively as design project supervisors, providing advice, and finally, evaluated their work. Whenever possible, faculty also recruited industry partners - firms that had an engineering design project that they were willing to give to a student team. Industry partners had to agree to be the "client" for the student team. This meant being available to meet with team members to describe their needs and give feedback on group output. Students were upper level undergraduates or beginning graduate students in various engineering majors. Students from different countries have typically been from different levels. They were told they would be working on an international student team. Teams worked with each other in English, and students had to possess English language skills to work on the projects.

Besides engineering faculty, social science faculty members with interests in group work and collaborative systems also participated in INTEnD virtual team research. Because they came from a variety of disciplinary backgrounds within the social sciences, including communication, telecommunication, sociology, organizational psychology and anthropology, a wide assortment of research approaches was used to study the teams.

Since the fall of 1998, a total of nineteen virtual teams involving participants in two or more countries has been formed within the INTEnD consortium. Most teams consisted of four to eight members from two locations. All were zero-history teams, formed at the start of a semester, and they worked over an approximately four-month period to complete their designs. For a subset of these teams, we have collected a rich and varied set of data on team interaction and work practices, which we describe in a later section. First, however, we briefly outline the types of technological supports we provided to the teams to facilitate communication and collaboration at a distance.

2.1.3. Communication and collaboration support for virtual teams. Because of the diverse institutions and locations involved, it was extremely difficult to provide a common set of sophisticated groupware technologies. Instead, we began with a mix of commonly available off-the-shelf communications tools. These included simple email, telephone, and fax communications, and where possible, ISDN-based video conferencing. We had experimented earlier with Internet-based video and audio conferencing, but because of their low quality, we opted to provide ISDN video [14]. We were unable to provide ISDN video in all locations, and in particular in China and Russia.

After our initial trials, we also concluded that some form of group collaboration tool was needed to create a common team workspace and a place for each group to archive its work. Because of the very different network infrastructures and access to software and communications services in the different country contexts, we ultimately resorted to the use of a Web-based collaborative system. In particular, we developed our own system called TeamSCOPE (Team Software for Collaborative Project Environments) which includes a shared file system, calendar, message board, a chat application for real time text interaction (see [24] for an overview of TeamSCOPE). It also provides certain types of "awareness" information to team members, including notification via the browser or email about recent team-related activities monitored by TeamSCOPE, such as file uploads and downloads, message postings and calendar entries, and real-time information about login status to support the chat feature. A beta version of the software was provided to teams in the spring of 1999, and a full working version was available for those teams beginning in the fall of 1999.

Beginning in the spring of 1999, we provided an ISDN desktop video conferencing system. In three of the INTEnD locations (MSU, TUD and UC3M), PC-based systems were made available to the student teams. These systems integrated real time audio and video with Microsoft's NetMeeting conferencing software. Hence, groups could establish chat sessions, share whiteboards, and share applications during their video meetings. For those teams without ISDN video, NetMeeting was available on its own.

All teams were provided with two types of initial training experiences prior to their project work. First, teams were shown how to work with the various communications and collaboration systems we provided. In addition, teams were exposed via an online training site to a number of transcultural communication issues they might face.

3. Data collection

To gain a better understanding of the ways in which distributed members used different communications and collaboration tools, and the types of communication and coordination problems they would experienc, we used a multi-faceted data collection approach. This approach incorporated both quantitative and qualitative indices of group activities.

We collected three types of quantitative information.

First, questionnaires were administered before and after each team's project experience. We opted to put questionnaires on the Web, and had students fill these out online in order to coordinate data collection in many locations. Pretest questionnaires were used to examine equivalency in interest, experience and skills across teams, as well as to assess expectations about working with their remote counterparts. Post-test questionnaires assessed such measures as the degree of satisfaction with the experience, comfort with the group's communication, trust in team members, the usefulness of the communication and collaboration tools provided, and assessment of the group's output. Second, team members completed weekly communication diaries, also using Web-based forms. Students were sent a reminder email each week, and then reported on the form whether they had any communication with their team, and if so, via which media. They also provided answers to a few brief questions assessing aspects of weekly team progress and communication. Finally, a third type of quantitative information was system usage data, including the frequency of use of TeamSCOPE and the number of electronic mail messages sent and received.

Three types of qualitative data were collected from a subset of the teams: observations of team meetings, interviews with team participants, and transcripts of team communication. When possible, research assistants in both locations (nearly all teams were two location teams) observed teams during their video meetings. During these observations, researchers made an audio recording of the interaction, which was later transcribed. In the anthropological style of "participant-observation," research assistants questioned the teams about cultural and power issues that occurred during international video-conferences. Further, unstructured interviews were conducted at the end of the projects to solicit feedback on how to improve virtual team experiences.

One final type of information collected on each team is an expert judgement of the team's engineering work by engineering faculty. This mainly occurred during the assignment of grades when faculty members were asked to rate the quality of the design work for each team.

Collectively these data provide us with detailed case studies of a several teams over time. We are in the early stages of analysis, and our discussion of findings below is mainly illustrative of our research approach. We focus in the next sections on several teams operating from spring, 1999 through spring, 2000.

4. Results

The multi-faceted research approach yielded a number of insights, which we here group into three broad areas: communication technology use patterns, group perceptions/attitudes about the experience, and contextual issues. In the first area, it is clear that teams developed their own styles and patterns for using the tools we provided. In the second area, it appears that global teams may at times succumb to problems due to lack of trust across locations. Trust problems may arise from differences in who controls access to critical information, as well as failures to adequately provide information about context to remote teammates, replicating Cramton's [3] findings. It also appears that trust-related problems are not independent of the communication styles that groups use. The third approach elaborates on the organizational context (cultural and power issues) that affect communication, co-ordination of activities, and performance. We elaborate on these results, showing the importance of the multi-faceted research approach, in this section. First we present some of the quantitative data on communication patterns and group attitudes. We then complement the quantitative findings with insights from observations, transcripts, and interviews with team members.

Table 1. Eleven teams from 1999-2000

Group Name	Design Task	Size and Time Period
Micro-channel	Improve heat transfer via microchannels	3 US-2 NL Jan.–Apr., '99
Evaporator Plate	Improve heat transfer via evaporator plates	3 US-2 NL Jan.–Apr., '99
Web Catalogue	Web-based agent for cataloguing info.	6 US-6 Spain Jan.–Apr., '99
Ladder Mill A	Components of wind energy generator	3 US-1 NL* Sep.–Dec., '99
Ladder Mill B	Components of wind energy generator	3 US-1 NL* Sep.–Dec., '99
Wheel Well A	Low volume metal bending process	4 US-3 NL Sep.–Dec., '99
Wheel Well B	Low volume metal bending process	3 US-2 Russia Sep.–Dec., '99
Roof Weld	Metal welding process for autos	4 US-4 Russia Sep.–Dec., '99
Animal IC Unit	Medical measurement device design	4 US-1 China Sep.–Dec., '99
Process Re-eng.	Manufacturing process redesign	3 US-2 Russia Sep.–Dec., '99
Ladder Mill C	Components of wind energy generator	3 US-2 NL Jan.-Apr., '00

* On these two teams, a third Dutch student worked as a coordinator/liaison, because projects were related to each other. He was not really a full member of either team.

Groups are referred to by the project task on which they worked. Table 1 provides some general descriptive information about eleven virtual teams.

This is not an exhaustive list of INTEnD teams. It includes those formed after we put into place PC-based video-conferencing in the US, Netherlands and Spain, the

TeamSCOPE groupware, electronic mail traffic tracking, and observation of team meetings in the US and Netherlands. All eleven groups, therefore, had the same communications platform, except that spring 1999 groups only used a limited beta version of TeamSCOPE.

4.1 Quantitative data

4.1.1. Communication patterns. Weekly diaries and system monitoring of electronic mail traffic revealed the frequency with which team members used the various communications tools over the life of their projects. The average weekly use of video-conferencing, telephone and electronic mail for five of the eleven groups is provided in Figure 1. Video-conferencing was not available for the Wheel Well B, Roof Weld, Animal Intensive Care Unit, and Process Re-engineering teams, and data has not yet been compiled for Ladder Mill C. The Web Catalogue team did not complete the diaries.

The line charts depicted in Figure 1 reveal quite different usage patterns for the available media by each of these groups. Most used video meetings quite regularly, with 1 and sometimes 2 meetings per week (Ladder Mill A, Microchannel, Wheel Well A), while others used it much less heavily (Evaporator Plate). Some showed heavier use of email, particularly near the final deadline (Ladder Mill A and B), while others interacted more via video at the close (Microchannel). Ladder Mill A increased both video and email use as the final deadline arrived, while the Evaporator Plate group did not communicate more heavily at the final deadline.

One aspect of the weekly communication that seems at odds with earlier research is the relatively low use of email, with many groups averaging only 1 or 2 messages per person per week. The explanation for this pattern relies on information from our team observers. It appears that in many groups, the local team members would work face-to-face, and then delegate the task of sending of email to remote teammates to one person. This biased the weekly per person averages for each team downward.

In addition, all teams exhibited virtually no telephone use, for which we offer two explanations. First, spontaneous use of the telephone for unplanned conversations was difficult due to time zone differences and the lack of a common office and number for all team members. Second, since phone conversations had to be planned in advance anyway, groups simply substituted video conferencing for the phone. This pattern of substitution of video for the telephone has occurred in previous settings where desktop video conferencing has been made available [7].

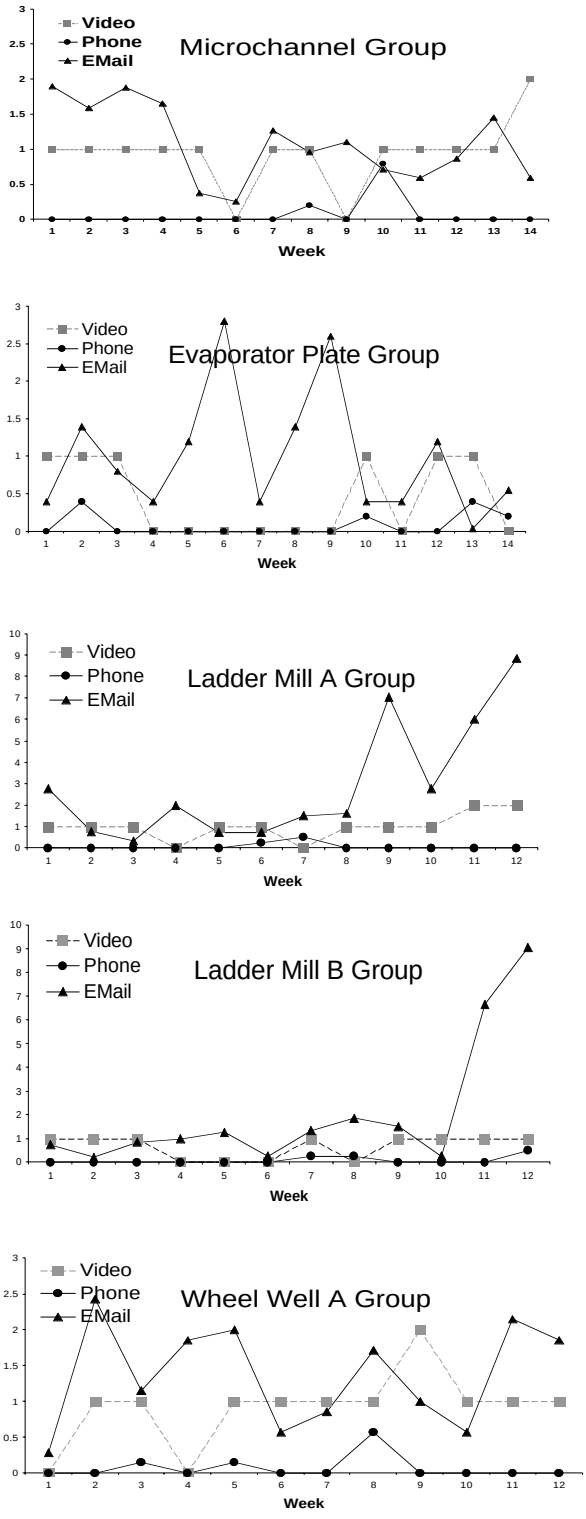

Figure 1. Average weekly media use in five selected groups

For groups beginning in the fall of 1999, we also collected data on the use of TeamSCOPE. Because TeamSCOPE is accessed via a Web browser, the server records the number of total pages requested by each user. We have aggregated this data into weekly team averages in order to see if there was differential use of this tool. As shown in Figure 2, teams varied greatly in their reliance on TeamSCOPE for sharing files and coordinating activities. Each participant accessed an average of 19.65 pages per week on TeamSCOPE. Average team usage across the 12 weeks remained consistently around 20 page requests with a drop only around week 10. However, the data shows that the Ladder Mill A (LA) and B (LB), and Wheel Well A (WA) teams used it more heavily. Ladder Mill A and B members used it more extensively throughout the project, while Wheel Well A members used it heavily in the middle, but less so at the end. In two groups, the Roof Weld (RW) and Process Re-engineering (PR) teams, TeamSCOPE usage was much lower, and died out in the second half of the project. Finally, another pattern of use was found in the Wheel Well B and Animal Intensive Care Unit (IC) groups, who used TeamSCOPE sparingly except for one week late in the project.

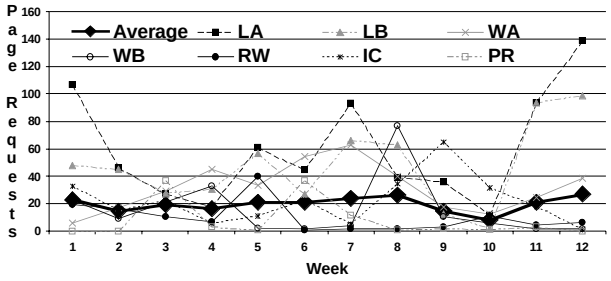

Figure 2. Weekly TeamSCOPE use by teams

The weekly communication and TeamSCOPE usage data suggest that the teams each developed their own patterns for communication and coordination, choosing to use particular types of communication tools at particular points in the project. This data suggests that teams appropriated the technology in group-specific ways, replicating a finding common in research on group use of technology [18, 22]. When combined with qualitative information from observers and interviews, the hypothesis about appropriation of technology is both strengthened and extended.

4.1.2. Group perceptions/attitudes. The results from the final questionnaire reveal differences in the perceptions of groups about their experiences. Here we report on three outcome measures: 1) the extent to which group members achieved real consensus on their designs, 2) the extent to which group members trusted their local and distant teammates, and 3) the extent to which they liked and felt comfortable interacting with their local and distant teammates. These outcomes were measured by multi-item scales in a questionnaire distributed at the end of each group's project. Table 2 provides mean scores for each measure, broken out for each location in each team.

Analyses of variance show a significant effect for both team and location on degree of agreement with the group's solution, trust in distant teammates and comfort with local teammates. There were also significant team differences for comfort with distant teammates, but the location effect was not significant. Significance tests, however, are rather limited, due to the small number of groups and people in various locations (e.g. there is only one person from China). Rather, here we point out just a few scores that relate to our discussion of qualitative findings below.

Table 2. Mean scores for consensus, trust and comfort across groups*

Team **	Location	Size	Agree w/ Group Solution	Trust in Local Teammates	Trust in Dist. Teammates	Comfort w/ Local Teammates	Comfort w/ Dist. Teammates
Micro-channel	US	3	4.67	4.56	4.56	5.00	5.00
	NL	2	4.00	5.00	5.00	5.00	5.00
Evap. Plate	US	3	5.00	4.11	4.56	4.89	4.67
	NL	2	4.00	5.00	3.00	4.83	4.00
Ladder Mill A	US	3	4.33	5.00	5.00	4.89	4.89
	NL	1	5.00	5.00	4.00	5.00	4.33
Ladder Mill B	US	3	4.67	4.89	4.78	4.78	4.89
	NL	1	5.00	5.00	2.67	5.00	5.00
Wheel Well A	US	4	4.50	4.50	4.92	4.33	5.00
	NL	3	3.17	4.11	4.11	4.33	4.11
Wheel Well B	US	2	4.83	5.00	4.78	5.00	4.67
	Rus	2	4.50	5.00	5.00	5.00	5.00
Roof Weld	US	4	4.50	3.83	4.00	4.83	3.83
	Rus.	4	4.50	4.67	4.25	4.75	4.42
Animal IC Unit	US	4	4.88	4.83	3.58	5.00	3.50
	China	1	4.00	NA	no data	NA	no data
Proc. Reeng.	US	3	4.33	4.33	4.22	4.44	4.44
	Rus.	2	3.50	5.00	4.67	5.00	5.00
Ladder Mill C	US	4	3.38	4.42	4.33	4.25	4.08
	NL	2	3.75	4.17	2.67	4.50	4.50

*Mean scores based on scales ranging from 1 = lowest to 5 = highest
**Only teams from Spring 1999 to present are included. The Web Catalogue team is not included due to missing data.

First, there did appear to be some problems with the Ladder Mill C group, which exhibited the lowest overall degree of agreement with the team's solution. The Dutch Wheel Well A members also reported a somewhat lower level of agreement with the group's solution. Dutch Ladder Mill C team members also reported a relatively low degree of trust in their American teammates. Interestingly, this lack of trust was not shared by their American teammates. Lower trust in distant teammates was also reported by Dutch students in the Evaporator

Plate and Ladder Mill B teams. On the other hand, there was a rather high degree of trust in distant teammates exhibited by the Ladder Mill A and Microchannel group. We will discuss each of these groups later, relying on multiple observers who offered insights into group dynamics that explain these different outcomes.

4.2. Qualitative data

For many of the groups, we have an extensive set of qualitative data, including observations of team video meetings, transcripts of audio recordings of these meetings, and interviews with team members. In six of the cases -- the Microchannel group, Evaporator Plate, Ladder Mill A, B and C and Wheel Well A -- this qualitative data was gathered by a multidisciplinary virtual team of researchers located at the Delft University of Technology and at Michigan State University (MSU). In both Delft and MSU, one or two observers attended local and international design meetings, observed activities, and questioned participants at the end of meetings. Additionally, observers produced a series of "transcultural" incident reports to help us identify when problems arose due to different communications regimes, working styles, and other cultural differences. These practices gave us multiple vantage points from which to understand team interactions. The observers periodically discussed their findings and impressions and also shared transcriptions, observation notes, transcultural incident reports, and interviews using our collaborative tool, TeamSCOPE.

The qualitative data helped us understand and explain quantitative results, and enabled the researchers to develop more detailed team profiles. Moreover, having such data as the transcultural incident reports allowed contextual analysis of cultural and power issues in relation to co-operative activity and team performance. Several insights resulting from the triangulation of qualititative and quantitative data are presented below.

First, observers complemented the communication frequency information with concrete examples for the ways in which each group developed its own style of collaboration and communication. For example, they recorded that the Microchannel team engaged more than other teams in social (non-task) interaction, and relied more heavily on video meetings for most inter-location exchange. We refer to them as the `social group'. We have labeled the Evaporator Plate team the `pragmatic group' because they were more focused on the outcome of the group efforts and rarely engaged in non-task interaction. The two Ladder Mill teams working in the fall semester of 1999 (A and B) were different from the others because there was a strong team learning effect, both in content and in ICT use. The Dutch students were more knowledgeable about the task and had more experience using NetMeeting. They shared their knowledge with their less experienced US team members, and as a result, the team was more innovative in their use of the collaboration tools than other teams. Hence we labeled it `the technology transfer and innovation group'. The Wheel Well A group was labeled as the `limited sharing group' because the Dutch students felt that they did not get sufficient project information from the US students, who they felt had easier access to the client firm. Four weeks into the project, the Dutch students realized that the assignment was much simpler than they had assumed, and felt misled by the US students. In reality, the US students knew no more than the Dutch about the project, but, much as Cramton [3] experienced with her virtual teams, the perception of withholding information influenced team interaction throughout the project. Finally, the Ladder Mill C team appeared to be a 'low trust group' due to perceptions by the Dutch team members that their US teammates were not working as hard as they should.

In addition to revealing more general group interaction styles, qualitative data also showed how groups used collaborative technologies. Each team tended to continue using the media they initially had chosen to use in a consistent fashion over time; a pattern we call 'media-stickiness'. Some groups started with video-conferencing and continued doing so during the whole project. For example, the Microchannel (social) group, gradually used video conferencing more as a tool to socialize than as a tool to exchange project-related information. Using video each week for a fixed hour became part of their habitual way of working. On the other hand, the Evaporator Plate (pragmatic) group, ended the first video conference with the comment that e-mail would probably suffice to coordinate their work:

> (US-member): At the moment I think we might better think about it ourselves. Have an e-mail first about the ideas, like a brainstorm, with an e-mail within a few days or something.
> (Dutch-member): Would you want to set a date or something for the next time? (referring to the next video conference)
> (US-member): Well we still think e-mail is probably our best form of communication so we will keep in contact over that and re-schedule as needed.

After this decision, the group mainly relied on email. Because of such media-stickiness, groups engaged in seemingly irrational behavior, sometimes failing to take advantage of more efficient communications tools. For example, members of the limited sharing group were so accustomed to the use of video, that they would not use the whiteboard to exchange drawings. Instead, they tried to show technical drawings to remote teammates by

holding them up in front of the camera[3]. Occasionally, breakthroughs occurred leading to a change in media use patterns. Often such changes came when a group was seeking a "work-around" to a technical problem, or when one location came to realize that the group had to change practices or it would not finish. This happened, for example, in week 10 with the Evaporator Plate (pragmatic) group. The Dutch side of the team was not satisfied with the work of their US teammates. They realized that their US teammates were not reacting to emails, or were too ambiguous in their email responses. The Dutch students decided to use video as a way to force more action by their remote counterparts.

Qualitative results illustrated an interesting side effect in the Microchannel (social) group that appeared to result from reliance on fixed, weekly one-hour video meetings. Once they completed discussion of the week's project-related work, slack time remained because all had kept the time free on their schedules. Rather than simply hanging up, this group filled the slack time with social conversation, directing the conversation to more social topics such as discussions about the different cultures, countries, courses, leisure activities, etc. Over the course of the project, their discussions became more informal, and it was clear to the observers that they had become quite a cohesive team. We think that creating social slack time enabled the sort of group maintenance activities that are considered to be critical to group development [11, 12, 13]. It appears to have increased the effectiveness of the team, as the engineering faculty rated the performance of the social group among the highest compared to other teams. This relation between social slack time and team effectiveness represents an interesting direction for future research.

The Ladder Mill A and B teams appropriated the available communications tools in their own common way, largely due to an overlapping Dutch membership that facilitated transfer of know-how. There were three Dutch students who were roommates, and who worked together on these two teams. One student worked on Ladder Mill A, another on Ladder Mill B, and the third helped to coordinate the efforts of the two teams. These students had more familiarity with the topic than their American teammates, and also had high-speed Internet access directly into their home on the Delft campus. They thus had better access to the Web-based communication tools after normal working hours, giving a larger window of time for communicating with their American teammates. As a result, they wanted to use Internet-based NetMeeting so that they could work from home in the evening when the Americans were still at work. They became quite expert at NetMeeting, which, coupled with their project knowledge, gave many of their interactions with the American students an instructional tone (hence our technology transfer and innovation label). These teams created innovative uses of the tools we provided. For example, they found that even with a planned meeting time, there was ambiguity about when a video meeting would actually start. One team has to "dial" the other, but only wants to do so when they know the other team is all present, has the computer turned on, and has the application software open. Otherwise they get no answer, but don't know exactly why. These two teams solved this problem by setting up a protocol of first logging into the TeamSCOPE system. Then, when informed that the other location was also logged in, they opened a chat window to make sure their remote teammates were ready to initiate a video call. This illustrates how providing one form of awareness information - communication availability - aided virtual groups in coordinating real-time group communication.

Another set of qualitative findings adds richness to the quantitative data on group trust, and illustrates the sometimes unique insights that can come from having multiple, geographically dispersed observers watching teams in their local contexts. We have noted that the TeamSCOPE tool provides detailed "awareness" information such as a log of project file activity that team members see upon each login (e.g. who downloaded a file, who uploaded a file, who commented on a file, etc.). We believed that making team members aware of their remote teammates activities would help overcome some of the information inadequacies of dispersed teams discussed by Cramton [3]. She found that lack of communication from remote teammates (often due to simple errors or timing problems), gives others the impression that remote teammates are disinterested or are not actively working on the project. Hence we tried to "fill in the blanks" by automatically logging any team activity in their shared file directory. Students from many teams told us this was indeed helpful. However, in the Ladder Mill C (low trust) team, such awareness information had a negative effect. Dutch students purposefully placed work on TeamSCOPE a few days prior to video meetings to give time for review. Using TeamSCOPE, however, they verified their impression that the American teammates were waiting until only minutes before scheduled meetings to download and look over this work. This created a sense of distrust, although nothing was ever expressed in meetings. As a result, the Dutch students stopped uploading their work early, and waited until just before the meeting just like their American teammates. Overall, it created a rather dysfunctional working pattern, where each location held on to their work until just before their video meeting. Hence much review and revision time was lost. The American teammates, and their

[3] Due to the low resolution of the camera, this was a clearly inadequate solution.

observer, were unaware that any problem even existed, and we became aware of it only through inter-observer discussions. This highlights how the awareness technology can have quite unexpected effects depending upon the interaction with such factors as the level of trust between teams. It exacerbated low trust problems for the Ladder Mill C team. On the other hand, it helped to build trust in teams that were working well. This suggests that group technologies have a reinforcement effect on group dynamics rather than a deterministic one, in keeping with a social construction view of groups and technology [18].

Finally, transcultural incident reports, produced by team members in conjunction with anthropological researchers yielded additional contextualized insights into cultural and power issues in relation to cooperative activity and team performance [4, 5]. Many incidents highlighted how collaborative work and technologies are "socially constructed," with sometimes disparate meanings in different cultural settings. For example, in one early team prior to 1999 that included Chinese, Dutch and American participants, Western and Asian sub-teams favored use of different communication media for the project launch. One transcultural incident reported that the Chinese students believed that a project launch required first building social relationships, and therefore should occur over a rich medium such as video. Dutch and US teammates, however, were ready to immediately begin by specifying task objectives, and preferred to do this via email or online chat.

In summary, qualitative data not only enriches and complements the quantitative data, but also highlights dynamics that might have been altogether missed without such a multi-faceted approach.

5. Discussion and conclusions

We have presented preliminary findings gained from studying global virtual teams over time, using a multi-faceted research approach. Our goal was to illustrate the ways in which such a research approach provides new insights into virtual team processes. Our results have generated a number of useful insights that can be explored in future research, particularly in the area of technology appropriation, path dependencies in media use, and the interaction of technology use and trust.

In general there appears to be a mutual dependency between team cultures, and the way that the communication technologies are used. These styles of use of technology appeared to be persistent, and such 'media-stickiness' could be a result of team learning processes. Cook and Yanow [2] refer to team learning as ‘the acquiring, sustaining, and changing of intersubjective meanings through the artifactual vehicles of their expression and transmission of the collective action of the group.' We observed that teams learn to use a tool and subsequently mutually adapt the tool and the tasks so that they do not need to diverge much from their past experiences. Because of this past learning, path dependency in terms of tool-usage sets in.

We also observed a relation between the team communication patterns and the degree to which team members trusted each other. Trust problems may arise from differences in who controls access to critical information, but also in the specific way of using the provided technology. Some groups, for example, used videoconferencing as a tool to socialize in addition to exchanging task information. These groups created slack time to get to know each other, which consequently increased their mutual trust. The multi-faceted research approach hence yielded insight in the process of appropriating group technologies. It illustrated how such technologies as TeamSCOPE can have opposing effects, improving coordination if the group is working well together, but increasing problems if not.

As is the case with all research approaches, the multi-faceted research model has its own pitfalls. In particular the approach suffers from a number of coordination costs imposed by the reliance on a team of dispersed researchers. We faced difficulties in coordinating research activities in multiple locations, and in providing common communication and technological platforms across locations. We had to resolve many issues regarding roles and responsibilities of the different researchers, and had difficulty integrating the many disparate views on how to conduct the research and analysis. We suffered from problems integrating many separate data sets into a form that was usable for comparative purposes, and found ourselves overloaded with data. As Cramton [3] experienced, there were also severe coordination problems that resulted from having team members in different institutions, and with different local requirements. Working with inconsistent academic calendars, for example, proved to be one of the most intractable problems.

The multi-faceted research approach involved a team of distributed researchers, explored multiple virtual teams over time and used multiple methods across a range of qualitative and quantitative sources of data. In combination, the approach is able to acknowledge the complexity of researching distributed teams. Exploring multiple virtual teams over time increases the external validity of the findings [26]. Although single case studies can provide much greater depth of knowledge about team dynamics, the ability to compare across teams helps differentiate idiosyncratic behavior from patterns that are likely to be found again.

Having co-located observers helped immensely, as it

enabled researchers to describe cultural influences more accurately as well as processes that help develop a dispersed collective team culture [19]. In our case, we were able to generate a number of different team profiles. These profiles improve our understanding of team interaction styles and communication tool usage.

Finally, this preliminary analysis highlights the benefits of using triangulation across disparate sources of data. The full combination of data sources strengthened the arguments we could make about virtual team processes. One unique type of corroboration was the ability to verify observers' impressions across locations. Often one observer had the impression that the project evolved without many problems, while another noticed a number of frustrations from his or her side. Hence, flawed inferences based on a partial view of the group interactions could be avoided.

6. References

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