"What Have You Done for Me Lately?" A Case Study of Barriers to Collaborative Tool Adoption in a Manufacturing Engineering Setting

Elizabeth E. Wierba
The University of Michigan
School of Information
1075 Beal Avenue,
Ann Arbor, MI
USA 48109-2112
(734) 936-1755
wierba@umich.edu

Thomas A. Finholt
The University of Michigan
School of Information
1075 Beal Avenue,
Ann Arbor, MI
USA 48109-2112
(734) 764-6131
finholt@umich.edu

Michelle P. Steves
The National Institute of Standards and Technology
100 Bureau Drive, MS 8260
Gaithersburg, MD 20899-8260 USA
(301) 975-3537
msteves@nist.gov

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This study examined a collaborative tool intervention within a geographically-distributed engineering design team in a large automobile parts manufacturing company. The intervention consisted of baseline observation and data collection to determine user requirements, followed by supported introduction of collaborative tools that matched those requirements, and then additional data collection and observation to assess the impact of the collaborative tools on team performance. Results showed that, a small proportion (1/3) of the team adopted the introduced collaborative tools, which had a positive impact on collaborative work. Furthermore, workarounds already in use within the team, such as transmitting engineering drawings as email attachments, were sufficiently successful to inhibit exploration and adoption of alternative tools – even when these tools had desirable features as described by the engineers. Findings from this study suggest that collaborative tools must be clearly superior to existing practices to merit the effort of deployment, adoption, and subsequent use, since the burden of learning and mastering a new tool in a demanding and fast-paced engineering design environment may not outweigh the perceived benefits. Practical recommendations focus on the larger role of competing demands, inertia and prior practice in implementing collaborative tools in field settings – and on the challenge of measuring the impact of collaborative tool use.

1. Introduction

As American industry continues to meet the challenges of global competition, rapid change and increasing complexity, organizations have dramatically increased the number of employees working in geographically distributed teams [1, 9, 16]. Distributed teams are critical to a global organization's success because they allow knowledge to be shared across organizational boundaries and aid in the creation of new products and services [11, 13]. Furthermore, having the option of forming geographically distributed teams offers organizations greater flexibility [17].

Specifically, globalization of manufacturing has created a growing need for product development to occur among distributed teams, driving the use of collaborative tools [20]. Collaborative product development is the process of sharing information in the design and creation of products to greatly speed manufacturing [8]. Designers, engineers, and managers must make decisions based on analysis from shared data from many sources. In fact, today's product development efforts are dominated by communication, teamwork, coordination, meetings, negotiation, and conflict management [22].

While geographically dispersed teams may seem an attractive solution to global organizations, they face numerous challenges to effective performance, including coordination and communication barriers. While there are many technologies to facilitate distributed work, their impact on the performance of distributed teams in manufacturing engineering settings has not been systematically examined. Our research objective was to assess the impact of specific collaborative tools on current manufacturing practices. We aimed to accomplish this goal using observations of changes in manufacturing practices and processes related to the introduction of collaborative tools within a single team in a large corporation. Our approach was to use empirical measurement to assess the collaboration needs of the user team. We then deployed available applications, and subsequently collected empirical data to assess the impact of the collaboration tool implementation.

2. Challenges to effectiveness of distributed teams

Collaborations among product development teams are challenged by "round-the-clock engineering" that can span multiple time zones and involve workers from different countries. With little synchronous time, virtual teams have increased coordination needs for interdependent work [17], and must maximize asynchronous means of coordination.

In general, distributed teams often rely on technology-supported communications, such as telephones, electronic mail, and video conferencing, more than face-to-face communications to accomplish their [10, 11]. New technologies facilitate some group activities and collaborative product development by supporting synchronous and asynchronous communication, scheduling, planning, task management, document and application sharing, and desktop conferencing [7, 18, 23]. Desktop conferencing enables real-time communication to be enhanced by data or application sharing. It allows geographically distributed teams to communicate and share information as though they were co-located [12]. For example, previous studies have found that desktop conferencing is helpful for groups with text-based tasks and graphical information needs – particularly where two or more collaborators need to maintain a shared orientation, or common ground [15, 24].

2.1. Collaborative needs of engineers

While most distributed teams may benefit from desktop conferencing tools, we expected that these might be particularly helpful to design engineers involved in collaborative product development. Studies of engineers suggest that a heavy reliance on visual and graphic material underlies the basic functioning of design engineering. Henderson [4] describes the visual culture of engineering as one where co-workers communicate ideas via sketches, and often need to refer to drawings and designs to accomplish their work. Henderson explains the centrality of visual communication in engineering saying that a *"… shared visual literacy and ability to read encoded meanings can facilitate coordination or foster conflict in collaborative* *projects (p. 25-26)."* Thus, we anticipated that the collaborative tools used by engineers would be geared toward their visual culture to affect the team’s functioning. We examined how distributed team members typically exchange information and communicate, and how the introduction of collaborative tools designed to aid in the exchange of visual information affected the team's performance.

2.2. Effect of collaborative tool introduction on coordination and performance

A key issue in studying technology use in business settings is the impact it has on performance and process [12], and a common difficulty encountered by researchers is gaining access to measures of team and individual performance. One means to understanding the performance of distributed teams is to assess coordination. For instance, Herbsleb and Grinter [5] found that difficulties in coordination, such as knowing whom to contact for what, lead to serious problems in team members accomplishing their work. Furthermore, Herbsleb et al [6] found that the most frequent consequence of cross-site coordination problems was delay in resolving task-related problems, such as design errors. They explained that work issues that might be resolved quickly in a collocated setting were sometimes delayed by days or weeks as distributed team members tried to establish contact with one another. Following from this research, we believed that coordination and delay were appropriate measures of performance for distributed teams. Furthermore, we expected that such performance difficulties should decrease with collaborative tool use.

Thus, to assess the work and collaboration practices of team members we planned to ask: How do team members manage their work when synchronous time is minimal, what team or individual practices facilitate effective use of synchronous time, and which tools can ease the burden of geographic and time dispersion? Following tool deployment, we expected that performance difficulties should decrease, and that implementing collaborative tools that enhance visual communication should also be related to improved performance.

3. Method

3.1. The Research site

The research site was a US-based automobile parts manufacturing company with over $2.7 billion in global sales in 1999. At the time of our study, the company, which we will refer to as "Auto1," had over 14,000 employees at 60 locations in 13 countries. Auto1 sells exclusively to major automobile and truck manufacturers in North America, Europe, and Asia. Auto1 management approached us to volunteer a new design team as subjects for our research. The team had responsibility to bring an innovative automotive system to market, with anticipated sales of over $1 billion. The catch, and the driver for collaboration technology, was that product development would require a successful union of expertise among previously disparate business units within Auto1. These business units were working together for the first time across multiple time zones, addressing cultural differences, political and organizational challenges, and inconsistent information technology capabilities. Auto1 managers believed that the team would require the help of collaboration technologies to succeed, and they also felt that this team would be used to determine the value of subsequent cross-business product development programs. Thus, Auto1 management embraced collaborative product development and the tools to support it.

3.2. The product and team

The team identified by Auto1 managers was a product development group of approximately 50 employees. The team comprised several distributed sub-teams involved in a single project. To protect their anonymity, we will refer to the team as the CAR team, the two divisions as Division A (the dominant division of the team) and Division B.

One reason this team was selected was because it was early enough in the production process to remain intact throughout the life of our study (one year). When we began the study, the project was in the concept stage. During the course of our year-long investigation, the project progressed into the product intent stage, and then moved to the product release stage at the conclusion of our study.

This highly functioning team was ready to adopt new technology, yet it faced numerous potential challenges to collaboration inherent in its work structure. For instance, the design, development, test, and manufacture of the team's product involved integration of many components, requiring collaboration among team members in four countries, many of whom had never worked together and were un used to the unique cross-divisional, global arrangement. Engineers, designers, and managers were required to share a variety of data types within the dispersed team, including design data from different CAD applications, prototype test data, design analysis data, and manufacturing specifications. The customer requirements for this new product were not stable and the customer was not geographically near many designers, posing additional design challenges.

3.3. User-centered design and data collection

We began the study with a web-based baseline survey of the distributed team members. The survey questions focused on an assessment of the potential utility of collaborative tools that might be introduced to the team, and measurement of team communication, coordination and performance. All 50 members of the team were invited via email to participate in the study and to complete the baseline survey. No incentives for participating in the study were offered. 33 of the 50 employees completed the baseline survey, from 6 geographically distributed sites, in 3 countries. Respondents were predominantly male, 35 years old (s.d. = 8.46), with typical organizational tenure of 6.4 years (s.d. = 8.91). After the introduction of collaborative tools, 34 participants responded to a follow-up survey .

In addition, we conducted interviews with a subset of the team members to plan further implementation and support of the teams' collaborative needs. Twenty four semi-structured interviews were conducted, 10 in one site in North America, 11 at one site in Germany and 3 via telephone to Australia. The interviews ranged from 20 - 40 minutes. The interviews with the team members and management addressed work role and background, identification of local and remote collaborators, the current means of communicating with remote collaborators, and tools, obstacles and opportunities for remote collaboration.

3.4. Survey Measures

We collected background information to determine the participants' age, gender, tenure in the organization, and office location. This information was used primarily to characterize the research site and control for extraneous influences on our statistical analyses [19]. In addition, we collected information on work processes such as communication patterns across different media, to assess the team's collaboration practices and needs.

We measured CAR team members' receptivity to new collaboration tools with 3 items (on a 10 point scale) regarding their motivation to adopt an electronic calendar, availability and presence tools, and a shared, mark-up tool. These items have been used diagnostically in other similar studies [e.g., 21]. In the follow-up survey we were interested in documenting which tools the team had actually used. Thus, we asked participants (with 3 items, on a 10 point scale) to indicate how often they had used an electronic calendar (MS Outlook), a presence awareness tool (ICQ), and a desktop conferencing tool (NetMeeting[1]) in the last six months. In addition, we assessed the impact of the desktop conferencing tool deployment with 4 items. We asked if desktop conferencing changed the manufacturing design process, and if so, to what extent it had improved the quality, efficiency and speed of the design process (on a 7 point scale). The three items (on a 7 point scale) assessing coordination were were derived from Herbsleb and Grinter's [5] study. The two items assessing performance were derived from Herbsleb et al's [6] study, and asked participants to determine frequency and length of delays in work as a result of task-related difficulties. Participants rated local and remote co-workers in the CAR team separately for coordination and performance items

[1] Any commercial product identified in this document is for the purpose of describing a collaborative software environment. This identification does not imply any recommendation or endorsement by NIST.

4. Collaboration requirements and collaborative tool deployment

4.1. Baseline analysis

We performed qualitative analyses to determine the most frequently mentioned issues in distributed work arising from the interview data. To accomplish this we followed standard practices for qualitative data analysis [14, 3]. We constructed inductive code categories first by reading through the background interviews and creating an extensive list of all the issues mentioned. We subsequently clustered these into themes of related statements. We used the most frequently mentioned strategic themes to summarize the current practices and barriers in distributed work for the CAR team. We used descriptive statistics from the baseline survey to support our themes and to aid in recommending collaborative tool interventions within the CAR team. We found that the data fell into three themes: Coordination issues, reliance on email, and maximizing synchronous time.

4.2 Collaboration requirements

4.2.1. Coordination issues. Team members experienced difficulty due to incompatible time zones and scheduling common work time with remote team members. One participant expressed this problem as follows, saying:

…the very different time zones are the biggest problem [in collaboration]. It is nearly impossible to have all three continents on the phone at the same time. Most (of our) employees are used to the North America – Europe time difference. Australia is more difficult.

In general, respondents described experiencing frustration due to limited synchronous time they shared with co-workers in other time zones, difficulty in coordinating among multiple time zones (such as Europe, US and Australia), and delays in work. On average, team members reported 4 delays each month, with 90% encountering delays of a day or more when working with remote collaborators

Furthermore, team members described difficulty in scheduling common meeting times with both local and remote co-workers. Often, problems in scheduling stemmed from difficulty locating local co-workers who traveled frequently. Yet, problems in locating and scheduling were more pronounced with remote than local co-workers. Coordination issues were strongly related to delays in work.

4.2.2. Heavy reliance on email. To overcome the coordination issues inherent in remote collaboration, team members established norms to help them expedite their work. While these norms were resourceful adjustments to dispersed teamwork, they were cumbersome solutions for collaborative work problems. Specifically, team members described using email foremost as a tool for contacting remote team members. Email was used as the primary means for exchanging task requests, data, reports, designs and sketches. It was perceived as ubiquitous at the desktop, reliable, and well-understood.

Yet, these norms fell short of the respondents' needs. Team members encountered difficulties in exchanging email while traveling. Furthermore, participants described file transfer as sometimes slow and causing delays in work. File transfer was especially slow due to large file sizes (often CAD drawings), and because of incompatibilities in encryption standards, leading to cumbersome security procedures (using ftp, zipped files and passwords).

Finally, email did not offer a rich medium for information exchange. For instance, email did not easily allow users to identify or describe visual details, which are common in design work. As one participant explained:

It is difficult to discuss details over email. Unnamed components must be described to identify them to others, (like the second bow in the tube) since not all parts have names. It's very difficult to discuss this over email because communication is difficult and slow.

4.2.3. Maximizing synchronous time. One of the challenges facing teams distributed across multiple time zones is the scarcity of overlapping work times. CAR team members most commonly used the telephone for synchronous work, while a few team members used desktop conferencing tools, and fewer still used video conferencing. Often, team members coordinated synchronous meetings via email. For example, one participant mentioned that one *“may say (over email) ‘call me this afternoon, I have to talk to you about such and such.'"*

Typically, team members conducted meetings via the telephone in order to discuss coordination issues, plans, acquiring further information or details, and clarifying issues mentioned in email. Team members mentioned that they would like to use visual aids to enhance such meetings. Some team members sent faxes to simply and quickly exchange sketches or other materials. In addition, team members who discussed sketches, designs or other visual material, expressed the desire to have tools to improve mutual understanding of the material (such as being able to simultaneously point to problem areas).

4.3. Collaboration tool deployment

The baseline analysis found that while team members were often using email effectively for asynchronous work, it served as a barrier for synchronous work. We suggested implementing a desktop conferencing tool to minimize the delay of document exchange in synchronous time. Because of cost and availability within Auto1, and because of prior favorable experiences, CAR management selected Microsoft NetMeeting as their desktop conferencing application.

To improve both synchronous and asynchronous coordination, we suggested that awareness tools (such as instant messaging) and calendaring applications would be useful in helping distributed team members find one another and schedule meetings. A subset of team members were already using Microsoft Outlook for calendaring at Time 1, and this tool was supported within the company. In addition, we suggested that a presence awareness tool could help participants target their telephone calls to times they knew their distributed colleagues were available.

Initially, the Auto 1 management team agreed to the implementation of this full range of collaborative tools. Ultimately, however, only the NetMeeting tool was officially deployed in the CAR team. Auto 1 managers explained that they believed they would need to get permission from European Community authorities to share calendar information, as regulations exist to protect exporting employee data and privacy. This issue deterred the managers at the research site from pursuing the implementation of the calendar as part of this project, though local managers strongly encouraged individual use of MS Outlook unofficially. Furthermore, an awareness tool implementation was planned to follow the NetMeeting training and deployment. Yet, at the conclusion of the study, the research site had not expressed an interest in deploying the awareness tool.

In conjunction with the site management team, we identified a subgroup for early adoption of NetMeeting within the participant team who were selected because management believed they had an immediate need to collaborate with remote colleagues. We trained 15 team members in two US and two European locations. The one-to-one training involved a 15 minute introduction followed by a 30 minute guided use of NetMeeting in an actual desktop conferencing session.

5. Follow-up survey analysis and results

5.1. Level of adoption

From the responses to the baseline survey, the mean level of motivation to adopt new collaboration tools was high, at 7.94 (s.d. = 1.27) (on a scale from 1 to 10, where 10 indicated most likely to adopt, and 1 indicated least likely to adopt). 68% of respondents indicated a strong desire to adopt new tools: 64% had a strong desire to adopt an electronic calendar, 68% had a strong desire to adopt a presence tool, and 71% had a strong desire to adopt a desktop conferencing tool.

At the conclusion of the study, adoption and use of new collaboration tools was higher for some tools than others: 36% of the respondents reported some level of NetMeeting use, with 6%, regular use; 97% of the respondents reported some level of shared calendar use, with 82%, regular use; and 36% of the respondents reported some level of presence awareness tools, with 12% regular use.

5.2. Impact of collaboration tools

50% of respondents agreed that NetMeeting had an impact on the CAR team's work, with most agreeing that it improved the efficiency and speed of the design process. Of these 82% agreed that the efficiency of the design process had improved, whereas 59% and 47% agreed that the speed and quality (respectively) of the design process had improved. Of the NetMeeting users, 66% reported an impact on their work processes, compared to 37% of non-users.

5.3. Changes in coordination and performance

Table 1 compares participants' responses to coordination and performance items before and after the NetMeeting deployment (baseline vs. follow-up). The table indicates the frequency of participants agreeing with statements regarding coordination with CAR team members, as well as the frequency of participants experiencing numerous and lengthy delays.

Table 1. Frequency of participants experiencing coordination and performance difficulties (baseline vs. follow-up)

	Baseline (n=33)		**Follow-up (n=34)**	
Items	**Local**	**Remote**	**Local**	**Remote**
Coordination				
Difficult scheduling common meeting times	18%	48%	17%	40%
Difficult finding co-workers	24%	38%	23%	28%
Receive timely information about changes in plans	54%	28%	63%	40%
Performance				
High frequency of delays (+4 in previous month)	50%	42%	41%	36%
High average length of delay (one to several days)	48%	90%	61%	95%

In the baseline and follow-up responses, CAR team members reported greater difficulty in scheduling common meeting times with remote workers than with collocated workers – however, this difference was smaller in the follow-up survey responses. In the baseline and follow-up responses, CAR team members reported greater difficulty in finding co-workers at remote sites compared to their local site – but again, this difference was smaller in the follow-up responses. Finally, in the baseline and follow-up responses, CAR team members reported receiving more timely information about changes in plans at their local site compared to remote sites – with increases in the timeliness of information at local and remote sites in the follow-up responses.

Participants indicated experiencing delays in work involving both local and remote co-workers. In both surveys, a greater percentage of respondents reported a high frequency of delays involving local co-workers. The percentage of respondents reporting high frequency delays decreased for both local (9%) and remote (6%) co-workers. The percentage of respondents reporting a high average length of delay increased more for local than remote co-workers.

6. Discussion

Our motivation in conducting this study was to understand the impact of collaborative tools on the performance of geographically distributed work teams. The significance of this research area is highlighted by the growing globalization of work, which requires an increase in coordinated activity across dispersed sites and employees. Specifically, in the manufacturing sector, it is becoming common practice for engineers from different backgrounds and at different locations to combine their efforts to produce novel products. Our strategy to assess the effects of these macro-scale changes was a detailed examination of a representative geographically dispersed engineering team.

We designed a collaborative tool deployment strategy based on rigorous analysis of the team's requirements, and then instrumented the deployment to assess the impact of collaborative tool use on the team's effectiveness. Our requirements effort recommended three technology interventions: a tool for desktop conferencing (e.g., Microsoft NetMeeting for synchronous viewing of engineering drawings and documents); a tool for shared calendars (e.g., Microsoft Outlook); and a tool for presence awareness (e.g., ICQ). Due to resource constraints within Auto 1, and legal concerns with the export of personal data – like schedule information – outside the European Union, we were only able to pursue one direct intervention: a supported introduction of NetMeeting. However, based largely on our feedback, the CAR managers launched an independent effort to encourage shared calendar use. In addition, there was some spontaneous adoption of presence awareness tools. Therefore, through a variety of mechanisms, the CAR team did experience a significant increase in use of collaborative tools over the year-long period of our study, and that use led to a number of critical insights, which we discuss below.

6.1. The role of collaboration tools

We were most interested in levels of adoption and use of the recommended collaborative tools, and the relationship between collaborative tool use and any changes in team performance and effectiveness, based on comparison of baseline and follow-up survey measures. To place this effort in context with respect to our main tool intervention with NetMeeting, there are only two published studies on NetMeeting in the literature [12, 2]. In the case of Mark et al. [12], the study focused on room-to-room use of NetMeeting in an engineering design setting within an aerospace manufacturing organization, primarily as an adjunct to audio conferences. Data were gathered on four teams over a period of three months. In the case of Finholt et al. [2], the study focused on targeted dyads of remote users doing software engineering within a telecommunications organization, again, covering a period of three months. Our study extends on the nascent research on NetMeeting as a collaborative tool by examining the effect on performance outcomes following the intervention, and by probing adoption issues in an organizational setting.

6.1.1. Adoption and use of collaborative tools. We concentrated NetMeeting training on fifteen members of the CAR team judged, by their management, to have the greatest need for NetMeeting features. This strategy succeeded in exposing NetMeeting to a significant fraction of the CAR engineers (about 1/3). By the end of the study, shared calendar use was ubiquitous in the CAR team. Adoption of presence awareness tools was much lower, with a small number of team members (12%) regularly using presence awareness tools.

A critical question is why adoption of the calendar tool was so much broader than the adoption of NetMeeting and presence awareness tools. A key factor is that in response to our summary of baseline and requirements data, the lead managers within the CAR team made a decision to recommend use of the shared calendar tool. However, NetMeeting was also strongly endorsed by management. We believe an additional factor in the differential adoption rates was that the number of engineers who benefited from the relatively specialized capabilities of NetMeeting or presence awareness tools was much smaller than the number who benefited from the relatively generic capabilities of the shared calendar tool. That is, scheduling is a more universal need. By contrast, a tool for application sharing or presence-awareness at a distance appeals mainly to those workers who must collaborate with distant colleagues and must do so in real-time, as when viewing a common drawing or document.

Our interview data supports these conclusions. For instance, one US engineer conducted regular intensive collaborative work with a colleague in a European site that required rapid feedback. During the period after the NetMeeting training, this individual reported weekly meetings using NetMeeting – and that these meetings were critical in the resolution of key design problems. In comparison, the Division B manager of the CAR team observed that most of their work with EU colleagues was concentrated on a manufacturing site which had very poor network connectivity. As a result, NetMeeting use might have been less than team members desired, reflecting the low performance of the network links between the two locations. Specifically, in both the interview and in the baseline survey responses, US-based engineers indicated enthusiasm for a tool like NetMeeting that would allow desktop conferencing (e.g., 71% of all respondents, and 100% of US respondents reported a strong desire for a desktop conferencing tool).

6.1.2. Impact of collaborative tools. We asked team members about the collective impact of collaborative tool use on changes in the manufacturing design process. Looking at the whole team, 50% felt that changes had occurred. However, focusing on those team members who used the various tools, the numbers were different. NetMeeting users were more likely to have reported a change in work compared with calendar and presence awareness tool users. Second, when changes were reported, the primary impact across all collaborative tool use was on efficiency and speed, with a smaller impact on quality. This is consistent with the improvements in coordination and lower frequency of delay in work with regard to remote co-workers. In addition, perceptions of efficiency and speed improvements were positively correlated with the perception that distant co-workers provided timely information. This relationship suggests that use of collaborative tools did reduce some of the difficulties indicated in the initial round of interviews, such as interruptions in mid-conversation to email attachments with drawings.

6.2. Techniques for assessment and evaluation

The main focus of this research was characterization of the use and impact of collaborative tools within a representative distributed engineering team. However, this was also an opportunity to assess and evaluate collaborative tool interventions that could be generalized to other field settings. In this section, then, we present a summary of the strengths and weaknesses of the research strategy implemented in this study.

Our difficulties in conducting the research reflect the first crucial lesson, in terms of the assessment and evaluation strategy. Doing research in the field, within actual engineering teams, requires enormous cooperation and compromise. For example, we wanted to introduce three collaborative tools – but because of Auto 1 legal and operational concerns – were only allowed to formally introduce NetMeeting.

Second, we learned that overcoming inertia in organizational settings is very difficult. In other words, if a solution to collaboration issues already existed, there was little incentive for participants to change to another solution. This was true for NetMeeting use. Frequent users of email attachments found NM to be a benefit to them, but those less frequent attachment users did not seem to want to use the tool. As one participant put it: *"In our case, we find e-mails with attached files, having access to common data bases and utilization of Acrobat to be our most useful tools."* Similarly, another subgroup used desktop conferencing – but not via NetMeeting (they used PC Anywhere). The leader of the group explained that:

We're using PC Anywhere to call in over VPN with an IP address... We have software installed on a host computer set up in US, and I can call that software, it's CAD packages, and so we can do a virtual design review. And its been working quite well, its reasonably fast.

We found evidence where other tools were used to achieve some of the capabilities provided by NM. Even though the users of these alternate solutions were perceived by management to be technology savvy and early adopters of technology, these users did not adopt NM. Learning the new tool was not a problem, but there was little incentive for change.

Finally, our entrée to Auto 1 and early development of the project was greatly facilitated by the enthusiastic support of the VP for Human Resources in Division B – who approached us to volunteer Auto

1 as a research site. This VP played an essential role in helping us negotiate across the two divisions involved with the CAR project. The significance of this guidance reinforces the importance, particularly in field research, of a high-level champion within the field organization. Momentum on this project slowed considerably when our high-level champion left Auto 1.

6.3. Practical recommendations

The foremost conclusion of this study is that collaborative tools must meet a specific need to merit the effort of deployment, adoption, and subsequent use. For example, the requirements gathering effort conducted early in this project successfully highlighted difficulties, or constraints, experienced by the CAR team members when attempting to do cross-site work. At least for some of the CAR engineers, as indicated by adoption and use rates, the set of introduced collaborative tools met the identified needs. For others, the available tools still imposed too great a burden to learn and master, relative to the perceived benefits. Those who found existing solutions satisfactory, or had infrequent interaction with distant colleagues used NetMeeting infrequently or not at all. Finally, a number of engineers wanted to use the collaborative tools, but couldn't due to infrastructure deficiencies (e.g., poor network connectivity).

In addition, it may be the case that the emphasis on synchronous collaboration (e.g., NetMeeting) was at the expense of tools that support synchronous and asynchronous collaboration (e.g., Teamwave Workplace). Specifically, introduction of asynchronous collaboration technology might have been a useful complement to the synchronous applications, particularly given the small number of overlapping work hours between Europe and the U.S. However, it is unknown whether adoption and use of asynchronous tools would have also been vulnerable to deficiencies in the available network infrastructure and user.

A second conclusion is that identified targets for change, such as adoption and use of collaborative tools, need adequate support to ensure success. The level of support varies with the complexity and novelty of the proposed tool. For example, a factor in the widespread adoption of shared calendar tools within CAR was certainly familiarity with calendars generally, and the seamless transference of knowledge and practices with paper calendars to online shared calendars. By contrast, for most CAR engineers, NetMeeting represented a completely new tool, with no analogs from past practice. Therefore, in adopting NM, engineers were asked to master both the tool itself (e.g., operation of the interface, how to establish a connection, how to share an application) and also the choreography of working with a distant colleague via the tool (e.g., trading off control of the mouse, negotiating shared references, resolving failures and surprises). At least within the CAR team, engineers had much to do just in performing the required aspects of their jobs. While we were strategic in selecting deployment targets with greatest need for NetMeeting and high likelihood of adoption, it was unrealistic to expect that engineers would devote time to instruct colleagues in the use of a sophisticated and complex tool.

In this project, we made a significant investment of research staff time in one-to-one training surrounding the introduction of NetMeeting. The one-to-one training was a success, but probably not conducted on a broad enough scale to create a critical mass of users for this study's timeframe. Less successful was the approach of finding high visibility users to model NetMeeting use, and by example, stimulate wider adoption of the tool. Additionally, some of the users we identified as the most influential adopters of new technology had already taken the initiative with application sharing by using an alternative tool, which supports the finding from our requirements analysis about the importance of application sharing, but did not help the effort to broaden the base of NetMeeting users.

The foremost practical recommendation for future research on collaborative tools in field settings would be to anticipate competing demands in this type of research. Specifically, adoption of novel tools with accompanying novel practices is not something that unfolds on a time scale consistent with most projects. Therefore, researchers will confront the need to perform some level of "pump priming" – that is, there has to be some level of collaborative tool adoption and use to produce behavior and outcomes that can be used to evaluate the impact of collaborative tools. Realistic determination of resources required to produce use, particularly where none currently exists, is difficult. In this study, for example, we robustly documented the enthusiastic need for features contained in tools like NetMeeting, yet for various reasons, stimulating sufficient levels of use remained a great labor (one-on-one training, follow up visits, and on-going encouragement of use), which came at the expense of further research documentation and investigation.

In conclusion, the goals of this study were to inform both practice (selecting and implementing a tool to aid in remote collaboration in a global engineering manufacturing setting) and research (assessing the coordination and performance outcomes following implementation). Our study contributes to theory by partially supporting the need for a visual desktop conferencing tool in engineering, and the reduction of some coordination and performance problems concomitant with tool use. From the practitioner's perspective, we experienced moderate success with 1/3 of the team adopting NetMeeting following our intervention. The primary lesson derived from this study, relevant to both practitioners and researchers in this field, is that general need drives collaborative tool adoption in organizational settings to a greater extent than specific need (e.g., the success of the unofficial calendar deployment compared to the official NetMeeting deployment). Furthermore, field studies must acknowledge the role of organizational constraints and competing demands on participants, such that collaborative tool intervention meets their needs above and beyond the cost of learning to use a new tool.

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