Learning the Tools and Techniques of Geographically Dispersed Collaborative Design Via a Brief Student Project

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Abstract

Engineering design collaborations with personnel and resources distributed throughout the globe, once experimental and cutting-edge, are becoming the standard operating procedure for many companies. Graduating engineers now enter a business environment that requires a sophisticated understanding of collaborative design and the powerful new technologies that make it possible. Traditional activities like face-to-face meetings are being altered and even replaced by a suite of synchronous and asynchronous tools that integrate communications, brainstorming, scheduling, project management, and many other aspects of the design process. The University of Dayton, with three partner schools in Ohio, is preparing students to effectively respond to the new and unique challenges of these environments. One goal of this work is a course featuring interdisciplinary, multi-university engineering design projects with strong emphases on both modern internet-based collaboration tools and successful distributed design.

Between the 5th and 14th of July, 2000, we executed a pilot design project implementing a geographically dispersed collaborative protocol. We assembled a small group of students into a distributed design team and assigned a rudimentary project via an audio chat session. Most team members were prohibited from face-to-face interaction during the ten-day period. To communicate and share data, they were required to use either the set of collaborative tools installed on each member's personal computer or a telephone. Only two team members were allowed face-to-face interaction and to gain access to the actual design site. No other team members had first hand access to the design site; all information about the site had to come via the two team members' investigations and posting of the resulting information to the project's web site. This paper presents the results of the design project, an overview of the collaborative tools used, observations about executing design under this new protocol, and future directions for this work.

1. Introduction

A collaborative environment exists when a design team can create a product or system by fluidly integrating each team member's knowledge and good ideas into the evolving design. That these teams require excellent resources and training goes without saying. The pinnacle of a collaborative environment is a design team that simultaneously addresses design, manufacturing, environmental impact, marketing and economic issues, just to name a few. A geographically dispersed collaboration, or GDC, is one in which resources, especially personnel, are physically distributed. The goal of establishing a GDC is clear. A GDC is the model by which a team simultaneously maximizes the use of their resources while minimizing the "time to market" of their "product."

1.1 Examples of Distributed Collaboration in Industry

GDCs are one direction large firms are selecting to keep a competitive edge. As evidence, consider these intriguing examples of collaboration in the design activities of large cutting-edge companies and research teams.

- Scientists at NASA's Ames Research Center are developing a completely virtual engineering environment. The goal is to have engineers and scientists from geographically dispersed locations interact as virtual people in a virtual room performing design and analysis tasks[1].
- The Distributed Collaboratory Experiment Environments Program, supported by the U.S. Department of Energy, performs simultaneous research on both physical and collaborative sciences. A fusion research project is currently being conducted between laboratories at the Lawrence Livermore, Oak Ridge, Princeton, and General Atomics sites. Scientists can run experiments, process data, and discuss results while located throughout the country[2].
- Ford Visteon and MIT are engaged in a multi-million dollar virtual engineering environments research venture. Ford brings significant experience to the table. They used dispersed virtual development teams to pool engineering expertise and incorporate cultural influences in the creation of their globally marketed Mondeo platform [3].
- NCR implemented a corporate strategy of virtual teams in the development of their new Worldmark server. Engineers at 17 different locations in the United States, Ireland, India, and China collaborated on a daily basis in the designing, prototyping, and testing of the new server. The server was brought to market in eleven months (ahead of schedule) and on budget[4].
- Boeing, a long time leader in the development and use of geographically dispersed collaborations, employed "virtual teams" to develop components for the 767. Two teams, over 1000 miles apart, held "virtual design reviews" featuring simulation data and the 3-D visualization of assembly drawings that either team could manipulate on the spot while the other team watched [5].

Having this snapshot of the engineering world to come, we are compelled to prepare our students to be skilled practitioners in these challenging environments.

1.2 The Need for Understanding GDCs and Their New Challenges

Several reasons account for the current interest towards geographically dispersed collaborations. Advances in communications continuously improve the ability to transmit complex information between dispersed locales in the form of shared applications, files, video and audio. From a corporate perspective, GDCs are attractive for several reasons. With offices located throughout the world, differences in the workday due to time zone separation could significantly shorten product development or to-market times. Also, GDCs can bring together the necessary expertise for a project without relocation resulting in a better use of personnel and resources. Tied to this new approach to teaming, however, is the potential for new and different challenges in team dynamics. Consider these results from the recent research:

- Having a lack of synchronous work time, dispersed teams lose their identity as a team resulting in such barriers to success as the loss of "spontaneous" or "casual" communication, and the loss of social, emotional, and non-verbal information [6].
- The meaningful exchange of information tends to drop in relation to the distance of separation between team members. This usually results in poor team performance on a project [7].
- A typical co-located team member spends up to 70% of his/her time collaborating with other co-located team members. Clearly, this must change under a GDC protocol [8].
- Team activity normally accounts for 85% of project costs and there is, as yet, no solid data to approximate the increase to these costs due to dispersed collaboration. These costs suggest a need to establish metrics to demonstrate such benefits as reduction in product development time and personnel expenses to help screen projects to be sound, cost-effective candidates for dispersed work [8].
- Slightly to non-overlapping workdays results in inadvertent information censorship. Team members failed to identify all of the information a dispersed coworker might consider important[9].
- Dispersed teams can suffer from an "out of sight, out of mind" mentality stemming from a lack of good communication practices and failure to identify a clear, common purpose. With less importance placed on the other dispersed team members, important information is frequently delayed or omitted [9].

Anecdotal evidence suggests that, to date, failures far outnumber successes. To make matters worse, some of these failures have proven quite costly. A lack of understanding of GDCs played a significant role in their ultimate failure. Evidence also shows that the right GDC with the appropriate tools and education can produce a talented and effective team.

1.3 Distributed Collaboration Experiments in Educational Institutions

The execution of multi-university design projects has sharply increased over the past ten years. The goal of these projects has been on successfully developing or designing a product with less importance placed on the process, best utilization of the collaboration, or understanding the paradigms of GDCs. Universities attempting GDC projects typically choose to facilitate at least one group meeting between all of the project participants. These meetings tend to have a strong agenda including modularizing the activity and making key project decisions. The project headed by the University of Pennsylvania and Ohio State University (with partner schools Cooper Union, New Jersey Institute of Technology and Drexel University[10]) had bimonthly meetings over the course of their two-semester project to facilitate this. They deemed these meetings a necessity. Most GDC projects, however, had students meet at only the beginning and end of the project. This was the model selected by the Westinghouse Savannah River Company Project (headed by Clemson University with partner schools University of South Carolina, South Carolina State University and Georgia Institute of Technology[11]), the Gateway Coalition's Multi-year, Multi-University Project (headed by the Florida International University and Cooper Union with partner school the Polytechnic University of Brooklyn[12, 13]) and the Texas Space Grant (headed by the University of Texas at Austin and Texas A&M with seven other partner schools throughout Texas including Baylor and Lamar[14]). The initial meetings accomplished the above agenda and allowed students to familiarize themselves with each other. The final meetings were to make final presentations. A danger worth noting is that, like several of the failures in industry, the design process can turn from collaboration into peer competition.

2. The Experiment

As a pilot, we executed a design project implementing a geographically dispersed collaboration during a ten-day period in July of 2000. We assembled a design team consisting of four students and an additional member from a local company. Team members were given equal status; that is no team leader was appointed. A faculty mentor acted both as an advisor and as a liaison between the design team and the customer.

The project, a redesign of a lab space to a suite of faculty offices, was undisclosed until it could be unveiled simultaneously to the design team members at their respective locations via an audio chat session. Only two student team members, called “the local group,” were allowed to have face-to-face interaction and to gain access to the design site. The other team members were prohibited from face-to-face interaction during the ten-day period. To communicate and share data, they were encouraged to use either the set of collaborative tools installed on each member’s personal computer or a telephone. For the distributed team members, information about the design site had to come via the local team’s investigations and posting of the resulting information to the project’s web site. The next two sections present the problem statement developed by the team and summarize their final designs.

2.1 Problem Statement

Statement of Need: The University of Dayton’s School of Engineering resides in Kettering Labs, KL for short. The building houses the majority of the School of Engineering’s classrooms, offices, and laboratory space. Civil Engineering uses a lab space located on the first floor as storage space. The existing floor plan and an interior shot of the lab’s largest room are shown in Figure 1. This lab is situated in the middle of space otherwise used by the Department of Mechanical and Aerospace Engineering (MEE). A recent space audit by the School of Engineering has advanced the notion of moving three members of MEE from their current offices into a new office suite on the first floor to consolidate the department. The new suite of offices will be located in the space currently occupied by the civil lab, which has an area of approximately 800 square feet. To accomplish this, a suite of offices for faculty and graduate students must be envisioned for the space.

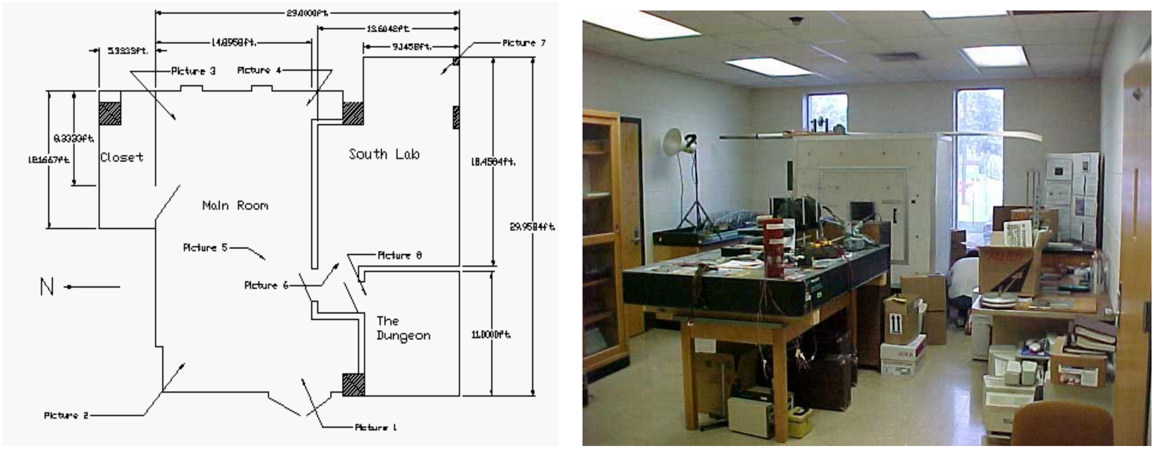


Figure 1. The existing layout of the laboratory space (L) and a photo of the interior (R).

Design Requirements: A design requirement is a specific property proposed designs must have. The design requirements for the office redesign are as follows:

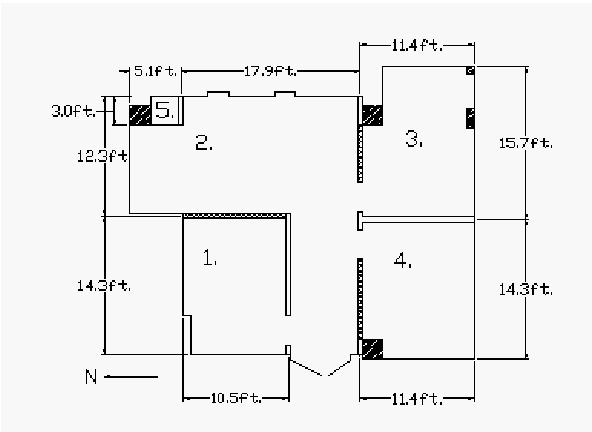
1. There must be at least three private offices for faculty members in the newly designed suite.
2. There must be a common space that serves as an informal meeting room and includes office utilities such as a copier, fax, microwave, etc.
3. The suite of offices must include proper support services for phone and network connections as well as electrical and lighting utilities.
4. The office space must meet all relevant (building, fire, etc.) codes.
5. The exterior walls of the space must remain as is. The interior walls can be eliminated.
6. Structural columns are immovable and must be included in the redesign.

Design Criteria: The design criteria pose the basis of evaluating competing designs that meet all of the design requirements. The design criteria for the office redesign are as follows:

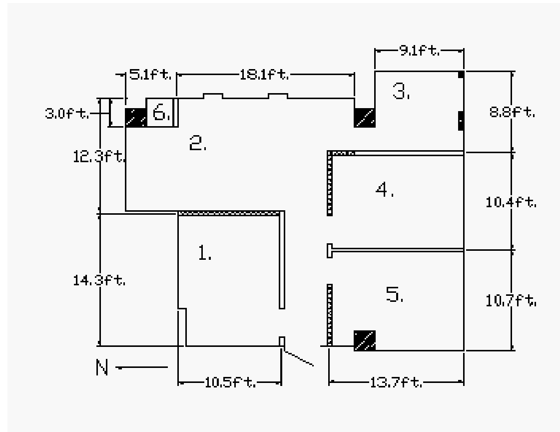
1. In addition to the design requirement that the new suite possess three faculty offices, gaining faculty or graduate student offices in addition to these is highly desirable.
2. The structural columns must remain part of the space. Integration of the columns into new walls should minimize their intrusion into office spaces.
3. Each faculty office should have an exterior window.
4. The suite should be designed in the most environmentally conscious manner possible. Specific areas of concern are lighting and carpeting.
5. Certain operations must be performed regardless of cost to transform the lab into an office suite: removal of existing interior walls, installation of new walls, installation of utilities, etc. The cost for all remaining aspects of the design should be minimized.

2.2 Final Designs

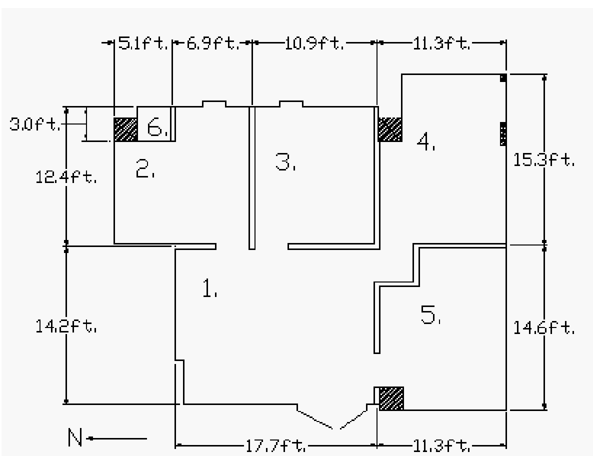
Four final designs were generated, identified as Layouts 1-4 in Figure 2. The designs addressed all the issues stated in the problem definition, though certain information, like the environmental concerns, are not provided here.



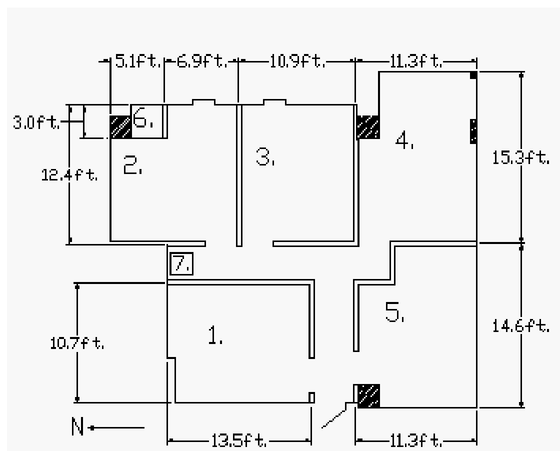
Layout 1



Layout2



Layout 3



Layout 4

Figure 2. The four proposed floor plans

- *Layout 1*: This plan provides the largest office spaces of the proposed layouts. The design includes three offices and a conference/common area. The network hub is off of the common area (room 2). The offices have windows that allow natural light to enter from the common space
- *Layout 2*: This layout offers three offices that are slightly smaller than those in Layout 1. The office space includes a conference area (room 2) and a smaller library/lounge (room 3).

- *Layout 3*: This plan provides four offices (only rooms 2 & 3 have windows), a common area (room 1), but may cause concern because of the location of the network hub closet in one of the offices.
- *Layout 4*: This layout offers five offices (only rooms2 & 3 have windows) with a nook (7) for the copier and printer.

When viewing the final designs, note the following items:

- *Exterior Walls:* Only the east wall is an exterior wall (top of the layout figure). Larger exterior windows or the addition of windows was sought. Facilities Planning and Construction Management communicated to the design team that this was not a possibility.
- *Network Hub / Computer Closet*: A network hub is located in the Northeast (upper left) corner of the space and cannot be moved. Computing Services needs infrequent access to the network hub. Given an office situated in this corner of the space, the network hub's closet represents a mild inconvenience to that office's occupant.
- *Crosshatched Walls and Beams:* Crosshatched interior walls contain windows that begin at approximately waist height and extend to the ceiling. There are also several 2'x2' diagonally hatched beams which are load bearing and cannot be removed.

3. Collaborative Tools

The tools selected for our dispersed collaboration were Lotus' Quickplace, Microsoft's NetMeeting, Yahoo's Messenger, and the telephone.

- *Lotus Quickplace*: Quickplace was selected as the asynchronous software tool for several reasons. First, being browser driven as shown in Figure 3, there was no need to install software on each participant's computer. Second, Lotus provides free 45-day trials via their Quickplace web site (qp2trial.quickplace.com) creating no need for our own server. Third, the software combines good functionality and ease-of-use with a clean interface. The site managers were able to quickly set-up a site giving the design team a high level of access while maintaining managerial powers over the site for themselves. Quickplace proved very useful for the storing, exchanging and editing of information. Early

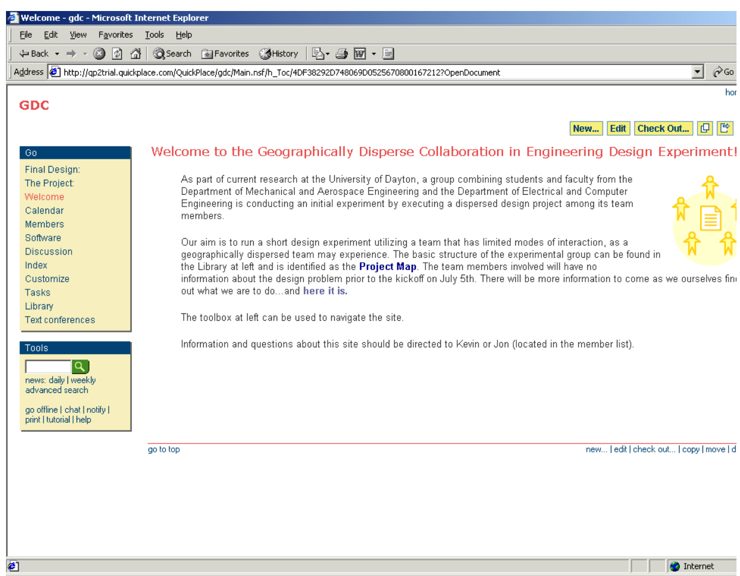


Figure 3. Lotus Quickplace was the team's browser driven asynchronous tool.

misunderstandings about the software did lead to problems with exchanging and editing of documents. These problems were quickly remedied however. Although our 45-day trial period ended long ago, the design project's site was still available at qp2trial.quickplace.com/gdc on last check. Readers are encouraged to browse the site if it is still available and offer feedback.

- *Microsoft NetMeeting*: NetMeeting, shown in Figure 4, facilitates file, application, and desktop sharing, whiteboards, and audio- and video-conferencing. NetMeeting was not used for video-conferencing for several reasons. First, several of the members of the design team did not possess the bandwidth to make video-conferencing worthwhile. Second, we did not strive to have video because of the results of recent studies that essentially conclude that if video isn't high quality and easy to use, it actually acts to the detriment of the project[9]. Please note that a design project was selected for which video was not thought to be critical. NetMeeting, originally considered the most important software tool in the process, was used significantly less than the asynchronous tools of Lotus Quickplace and the low-level synchronous functionality of Yahoo Messenger; the scope and time frame of the project seemed simply to match these capabilities. A method for predicting usage levels could prove to be of significant value. NetMeeting does provide good functionality and ease-of-use with a clean interface, but its higher bandwidth demands cause limited use. Eliminating audio- and video- conferencing from its tools improved our performance. Information about NetMeeting, including downloads, is available on the Internet from Microsoft at www.microsoft.com/windows/netmeeting/default.asp.

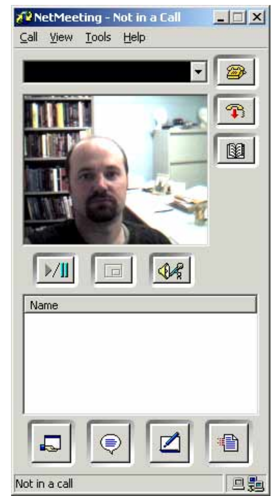


Figure 4. NetMeeting, a synchronous tool.

- *Yahoo Messenger*: Our tool for online "awareness" was Yahoo Messenger. The members of the design team were requested to run Messenger whenever they were online and able to work on the project. As a result, Messenger allowed team members to quickly survey when others were available. No phone calls needed to be placed. The hope was that spontaneous teaming would occur from this level of awareness. A limited amount of additional teaming did occur, but not as much as was hoped. Yahoo Messenger provided our text and audio chat tools used extensively during the project. Audio chat was a necessity in that certain members of the design team, when working from home, had only one phone line. They could either be participating in team activities via their computer (and using audio chat) or participating via a conference call. Information concerning, including downloads, Yahoo Messenger is available at http://messenger.yahoo.com/.
- *Telephone and Conference Calling*: Although not a software tool, the telephone was still a tool selected for the project. All preferred conference calling to audio chats when discussion was the only item on an agenda. As mentioned earlier, when electronic documents required viewing during a conference call, team members with only a single phone line had to download

all of the documents prior to the meeting. This was a hassle and an activity the team attempted to avoid as the project pressed on.

4. Observations

There were many observations made about our execution of a geographically dispersed collaboration, the most pertinent of these are listed below. The observations are divided into four general areas: tool use, team dynamics, infrastructure, and project specific issues.

4.1 Tool Use

In this list, we detail problems resulting from the use of software tools to facilitate a “virtual” work environment.

- **An expert user can provide specific training.** Team members were provided no training in the software tools. Therefore, tools were not used to their full potential in the early phases of the project. Necessary skills were acquired quickly as the project progressed, although differing skill levels posed problems throughout. In fact, these types of software are typically user-friendly and intuitive. Thus, the team members did not desire general training but an expert to answer specific questions and offer oversight was.
- **Standards need to exist for information inclusion/exclusion in a worksite.** Two simple examples are using a task list and making minor revisions to a document. First, the “Task Bar” in our asynchronous tool was not effectively used for assigning tasks because participants were not sure as to when a task merited being included in this list. The assumption made by the team was that only the highest level tasks should make the task list such as “problem definition due” or “conceptual designs due.” The result was that tasks assigned solely through the task list were frequently ignored because it was deemed a useless resource for performing real work on the project. Also, tasks that resulted in real work being performed were never posted to the list. As a second example, documents frequently receive minor editing. Members questioned whether a document with simple changes should take the place of the previous document, appear next to the previous document, or appear in a folder of edits to the parent document. Versioning is clearly a critical activity.
- **Standards need to exist for organization of the asynchronous site.** Organizing the limited quantity of information at the asynchronous site was not a challenge early on. It became a challenge as an increasing amount of information to store, read and manipulate was generated. No method of effective management of the information was realized. Our heuristic was to let the site managers keep the site organized as they saw fit.
- **Site/Document continuity is important.** No restrictions were placed on the software implemented by the individual users. Documents of similar content were, inevitably, posted in different formats and lacked continuity. Documents appeared to be different which should have appeared to be intimately related.
- **Text chat is not a viable substitute for a real meeting.** Many of our meetings were held via text chat. Text chat frustrated the meeting participants due to the slow exchange of detailed

information. In comparison to face-to-face meetings (or a conference call), text chat grew cumbersome. Short meetings to discuss specific topics may be successful via text chat. Once the scope or length of the meeting grows, text chat is not an effective option. Additionally, the "richness" of text chat is low making abstractions difficult to obtain. Text chat discussions occurred on the most superficial level, avoiding debate about underlying properties, ideas or goals.

- **Using the asynchronous site is not just a convenience; it's a necessity.** Member's used the site when convenient, not as a method for staying informed on the status of the project. In fact, updates to the site were often unchecked until the last possible minute, either just prior to a meeting of just prior to a deadline. Furthermore, regular posting of information provides a motivation for regular viewing of the site. If no one posts, no one views.

4.2 Team Dynamics

In this list, we detail several problems the members encountered in working effectively as a team.

- **Members of the team worked in an uncollaborative mindset.** Work was neither assigned to sub-teams nor did we choose to work as sub-teams. For example, team members did not opt to discuss project specifics online when they could individually accomplish the minimum requirements of a given task. Shared whiteboards and applications were available but went unused (although partly due to infrastructure limitations). At meetings, when tasks were being assigned, no sub-team decided to share results prior to the next meeting in order to produce a better result. It seems as though the geographically dispersed team members viewed each other more as contractors than as integral to the process. The literature implies that non-scheduled interactions are valuable; encouraging these online seems like a significant challenge.
- **Timing issues became more critical.** Timing provides a good example of the idea that the geographically dispersed process appears to exacerbate typical team interactions. We question whether the timing was actually more critical or whether the perception was that the timing was more critical. Casual interaction barely exists so deadlines were met with an "all or nothing" attitude. "I'm almost done, I'll get this to you later today" is somehow transformed at (geographically dispersed) meeting time to "I'm not done so you're stuck until the next scheduled meeting time."
- **Equal levels of seniority created equal levels of apprehension.** All team members were regarded as equivalent in seniority, a decision made at the outset of the project. As a result, the team was unable to effectively delegate activities because no individual would take the lead and assign them. Ultimately, volunteers were solicited for each task, a laborious method. In addition, members offered no genuine criticism or praise for other member's ideas (weakening the decision analysis). Questions of accountability were raised. Suggestions were also made to use Electronic Meeting Software (EMS) to allow for anonymous praise, criticism, and voting on ideas. In hindsight, appointing a project leader would have been a good idea. The importance of good, clear, team level leadership in a dispersed team is underscored by this observation.

- **A task assigned to the entire team was a task assigned to no one.** Team members could propose tasks to the entire team. Tasks proposed in this fashion were, frequently, not addressed except by the member proposing the task. Two observations come to mind. One, the member posting the task felt obligated to respond. Two, members may have tried to shift individual tasks to the rest of the team to lessen individual workloads.
- **The *unfamiliar* team member was not utilized.** One team member, who was slightly older and an employee of a company, was not a peer of the student members. This member left initial meetings with no assigned tasks. Early involvement by this member was also limited, perhaps from being uncomfortable due to a lack of familiarity with the team. The other members, though not all personally acquainted, worked together better from the start. A member's level of involvement could possibly be related to their familiarity with the other members. However, infrastructure challenges, mentioned below, also factored heavily into this member's involvement.

4.3 Infrastructure

In this list, we detail the infrastructure problems encountered during the execution of the project. This list contains problems specific to our attempt to run this project in an academic setting involving students. Infrastructure problems are sure to exist in geographically dispersed projects. This list does not represent problems others will necessarily encounter but does include items that need to be remedied in any of our future attempts.

- **On occasion, text chat had to be used instead of audio- and video-conferencing and conference calling**. This was due to a combination of bandwidth restrictions, firewalls, and team members with single phone lines.
- **A firewall eliminated the possibility of a full team audio chat**.
- **The quality of audio chat amongst those who could participate was poor**.
- **Video could not be attempted due to bandwidth requirements**.
- **Two team members had only one phone line**. They could either use the phone or the computer, not both.

Conference calling was the ideal choice for discussions. The problem was that the two members with single phone lines were then unable to share in the current online information (unless they downloaded it previously and participated in a read-only capacity). So, using audio chat was the next best solution. The two members with the single phone lines could both participate in an audio chat and share the online information. The person behind the firewall, however, could not participate in the audio chats. The result was that meetings of the entire team required the use of text chat.

4.4 Project Specific Issues

In this list, we detail issues encountered during the project that were specific to choices we made. Whether or how they will be changed for the next execution of a project is still undecided.

- **We opted to let team members learn tools on the job**. This created an array of difficulties early on. As might be expected, the difficulties dissipated with time. Some level of instruction in the tools seems appropriate. An expert is suggested above.
- **The specific nature of the project was undisclosed until the project began**. This caused a significant amount of early inertia on the project. Some attempt at the pre-scheduling of activities may be in order.
- **The team size was mismatched to the scope of the project**. In an attempt to increase the number of interactions typical of dispersed team members, superfluous members were added. More care will be taken in assembling the next team.
- **Faculty mentor involvement in meetings gave those meetings more focus and direction than those occurring in his absence**. This occurred most probably due to the lack of a team leader. Meetings without the mentor were often drawn-out and less productive than those with the mentor present. The mentor's presence seemed to fill a vacuum created by the absence of a team leader. Task assignment and critical discussion, things that in ordinary meetings without leadership were difficult to do, were facilitated by the mentor's presence. This point is inherently tied to our decision of not selecting a team leader on a team member level. The mentor's level of hands-on involvement will be reconsidered in the next project implementation and the need for well-defined leadership at the team member level will be addressed.

5. Conclusions and Future Work

Our primary goal in running this pilot project was to gain exposure to geographically dispersed collaborations. We wanted to learn about these collaborations in engineering design through a hands-on use of the tools and techniques. As shown in our observations, we witnessed many aspects, good and bad, of dispersed collaboration. Fundamentally, we observed that dispersed collaboration is not an intuitive skill; individuals must be taught how to be effective players in dispersed teams.

Another goal of this project was to prepare for the execution of geographically dispersed engineering design collaborations in the classroom. Our first classroom design project will be run from January through May of 2001. We currently have commitments from Ohio University, Ohio Northern University and Wright State University to contribute both faculty and students to this effort from departments including Mechanical Engineering, Electrical and Computer Engineering, and Biomedical, Industrial & Human Factors Engineering. One of our continuing goals is to run dispersed projects in a classroom setting every semester. Our administrators and the instructors of our capstone design experience are enthusiastic about the future of this activity.

We are also planning to conduct a second project of greater challenge in the summer of 2001. The project is expected to include a larger team, a wider array of facilitating tools, a design project with more technical challenges, and more direct input and participation from industrial and government partners.

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