Team Learning through Computer Supported Collaborative Design

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Abstract

Colleges and universities have not traditionally educated their students in the benefits and techniques of collaboration. Rather traditional education has exalted the genius of the solitary scholar. Modern times demand otherwise of us, and educators must learn themselves how to teach collaboration. This is nowhere more evident than in the "design disciplines," those whose practitioners spend substantial portions of their professional lives designing things. These include engineers (mechanical, electrical, civil, software, etc.), architects, and writers.

This paper discusses the nature of collaboration in the design disciplines and describes innovations and studies in collaborative design education in which the authors are involved. A venue for collaborative design education and research is described as well.

Keywords — computers, networks and other technological developments relevant to CSCL, instructional strategies and approaches, instructional assessment issues.

1. Introduction

The modern workplace is dominated by collaborative activities. As products and services grow in complexity, collaborative work is becoming increasingly multidisciplinary. Consequently, educators must prepare their students for success in this mode of work.

This paper discusses how technology can usefully extend the collaboration process in face-to-face settings as well as prepare students for collaboration in the workplace. Also presented are reasons why current group decision support systems may not succeed in important areas such as design and collaboration education. An environment in which design teams can learn how to interact and succeed in their work is described.

2. Teams

A common practice in industry is to bring together people of multiple disciplines and expertises to achieve a common goal [Katzenbach91]. One of the greatest challenges in this setting is getting a group such as this to work together as a team. Each member brings his/her strengths (and weaknesses). The objective of the team approach is to develop solutions which are better than those any individual would likely produce.

"Team" is a familiar word and concept which has many interpretations. In this context, good teamwork results from listening and responding constructively to other's views, support and dedication to shared goals, and full participation. Good team characteristics also include shared leadership roles, individual and mutual accountability, collective work-products, and performance measures directly assessed from collective work-products. Members encourage open-ended discussion and active problem-solving meetings [Katzenbach91, Hutchins93].

To be successful, a team generally needs people who bring a varied expertises and who can fill a variety of roles --- organizing, evaluating, detailing, moderating, etc.

3. Traditional Meetings

Among all the events which occur during a team's work on a project, the most intensely collaborative and productive are often the team meetings. A meeting is a gathering of people with a purpose where communication among participants is the central activity.

Most meetings occur in an enclosed space with tables and chairs while the communication media are limited to verbal exchanges and visuals such as paper, overhead projection and video. Direct communication is largely limited to speech and the passing of documents.

As participants use the oral medium, the meaning of words and objects (sketches, charts, text, etc.) interweave to construct mutual understanding. If a team member is trying to explain how an engine works, for example, then the member may use photos, video, diagrams, graphs, and words to foster an understanding for others. Others in the team may use the spoken word and the other representations to query the expert on how the engine works and the terminology which describes it. Without clear communications, the team may spend hours needlessly debating before they recognize and correct a simple misunderstanding.

During a design project, a team travels through an abstract domain of ideas in which they collect, compare, join, discard, revise, etc. The path taken includes many decisions made along the way, and a group may use many decision making methods during the design process.

When a decision is made by consensus, all members usually understand the decision and are prepared to support it. In practice, consensus means that all members can rephrase the decision to show that they understand it, that all members have had a chance to tell the group how they feel about the decision, and that those members who continue to disagree or have doubts are nevertheless willing to give the decision a try.

Throughout the process, the design team tries to attain a mutual understanding of issues and solutions. When a group has a mutual understanding, they are able to move to consensus on a point.

The construction of a mutual understanding through dialogue includes both agreement and disagreement. [Burnett93] found a significant positive correlation between the amount of substantive conflict during invention and the final product quality. Substantive conflict appears to allow participants to fully explore the possible alternative courses of action.

4. Face-to-Face Meetings

Problems in traditional meetings include ideas that do not surface and are lost, time wasted on "political posturing," the serial nature of communications (i.e., discussions of one topic at a time), and documenting the meeting [Dallavalle92]. In recent years meeting rooms have incorporated telephones and television in order to permit live communication with distant conferees and for showing pre-recorded material (essentially "hard copy"). Computers have also been added to gather, organize and distribute information.

Distance collaboration offers obvious advantages but suffers from bandwidth limitations of current communications technology. To explore the ultimate promise of coming technology and to address directly opportunities present in most on-campus college settings, we consider face-to-face meetings.

5. Media in Meetings

Multiple media give individuals many ways to express their ideas in written documents, notes, sketches, graphs, tables, audio and video recordings, etc. A variety of formats allows others to view an idea from many viewpoints, increasing each person's chance of gaining an accurate understanding.

For example, the floor plan of a house gives no direct sense of vertical dimension. However, two drawings or a perspective drawing can make it possible to comprehend the third dimension. A dynamic on-screen walkthrough is even better. On the other hand, graphical instructions on assembling a bike without any text would be of little use. Words are generally helpful in describing how to make parts fit together. In a third example, the weatherman may say it is "cold" outside. For someone in southern California, "cold" may be 50 degrees while someone in upstate New York might define "cold" as 20 degrees. Without the numerical representation for the temperature, the meaning of "cold" is ambiguous.

In a collaborative design session, there may be other options for expressing ideas. When an idea is introduced, it may be rendered in multiple forms thereby increasing the chance of its being understood. Different ideas generally benefit from expression in different media, each medium chosen to best convey an aspect of the idea at hand. Furthermore, modern electronic communication can bring appropriate information from a myriad of sources in various media to a team. This access to global information resources prevents unnecessary delays and delivers information when it is most valuable and usable.

Good multiple media will free people to think associatively and attach comments to the ideas being presented. Team progress and reports may be thus built automatically during deliberation. Appropriate tools may also encourage multitasking in the sense of a person concentrating on the current topic without forgetting what s/he wants to say (whether or not that topic has passed).

When multiple sources of information compete for our attention, cognitive issues are raised. For example, most people are able to listen closely to one speaker yet give enough attention to others to permit them to detect enough content to earn a shift of attention.

The use of multiple media raises further cognitive issues. For example, the confusion present when multiple sources communicate within a single medium may be reduced when the sources are spread among several media. Multiple media sources may affect the level of interest generated and may serve either to stimulate or distract participants. The sequencing of information may be easier when alternate media provide alternate channels for acknowledgment of receipt.

Over the past 10-15 years various academic and commercial organizations have built and used computer-supported group decision support facilities

[Nunamaker93, Marca92, McLeod92, DiPietro92]. These have incorporated networked personal computers running group decision support software (GDSS) which coordinates idea generation, evaluation and decision making [Stefik87].

Because most GDSS designs emphasize information management instead of collaboration support, these traditional decision-support systems are not consistently effective in meetings [Marca92]. Many GDSSs are highly structured and have tight synchronization points. The computers are a central part of the meeting and force the group to follow a meeting script dictated by the software. A professional facilitator may be required for each meeting. These systems generally do not foster learning of group dynamics and how to interact but instead simply follow a model decision process algorithmically.

Thus GDSSs seem to assume that teams cannot succeed by themselves forcing control structures on the team. The ideal system would not assume this; it would be flexible and allow people to share ideas and information with a less enforced structure. Users would be empowered by the technology.

6. Collaborative Learning Through Design

To be productive in design meetings, the participants must be familiar with roles, activities, and protocols which are all part of meetings. Training sessions must familiarize participants with meeting roles such as those described by [Pfeiffer91] and with meeting activities such as generating ideas, negotiating, assigning action items, reviewing existing items, and presenting.

A group "history" should be established through team building. Introduction of an electronic meeting system into an ad hoc group project with little or no group history tends to increase the degree of apprehension about meeting and about communications media [Chidambaram93].

The Rensselaer Design Conference Room (DCR) has been created with these things in mind. The DCR is a conference-sized room accommodating 6 to 10 people. Participants generally come to this room with their individual ideas, information, documents and visuals ready to present or otherwise inject into a team discussion. The DCR has access to all network services.

The physical configuration of a DCR conference is sketched in Figure 1. The table has a central hexagonal portion containing "public" screens (large color monitors) in front of each pair of team members. Three wings extend from alternate edges of the central hexagon. Each wing houses two workstations for the use of individual team members. All screens are buried below eye level so as not to impede visibility and dialog among team members. This table design gives each participant a private workspace as well as access to the DCR Collaboration Network (CN).

Participants are able to take and cede control of the "public" workspace via protocols administered by this software. They are able to move items back and forth between public and private screens in the course of a meet- ing. This electronic activity is complemented by active oral dialog with significant synergy.

The Collaboration Network is viewed as *hyper-group-ware*; that is, a framework into which applications soft-ware, both single user and groupware, can profitably be imported for joint use.

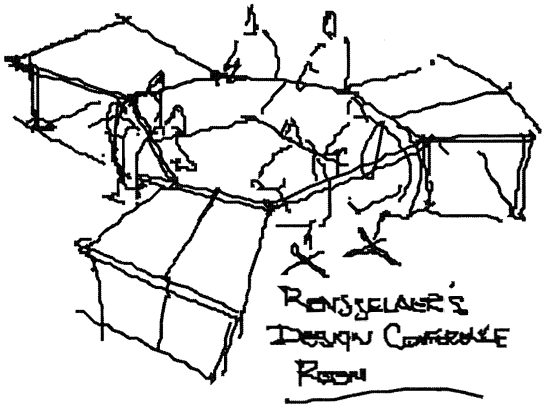

Figure 1. Sketch of DCR table configuration.

A form of anonymity in this face-to-face setting is available via a "chat" program. Anonymity may reduce apprehension and increase focus on ideas, yet in the DCR, everyone still has the advantage of a full range of visual and oral cues. For each project, there is storage space for team and individual files. A teams can form sub-projects which arehandled hierarchically within a main project.

The main CN interface is shown in Figure 2. It uses a schematic table top to show all participants in their posi -tions around the DCR conference table. There are three participants in this specific collaboration session, as indi- cated by the shading of their heads. Each has an appropriately oriented copy of this table on his/her private screen. Anne is in control of the public screen, and Cheryl has requested control. The person in control can drag her cursor smoothly from her private screen to the public screen and back again, shifting both mouse and keyboard control between computers. Moreover, the clipboard fol- lows silently, carrying data between domains. To support active give and take, a user not in control of the public screen can drag her/his cursor onto the public screen where it turns into a personalized "ghost" cursor to serve as a pointer during discussion. The buttons in the center allow a user to interrupt ("!") or freeze ("stop sign") the control of the public screen. These media sharing/control protocols evolve as we learn more about better meeting support mechanisms.

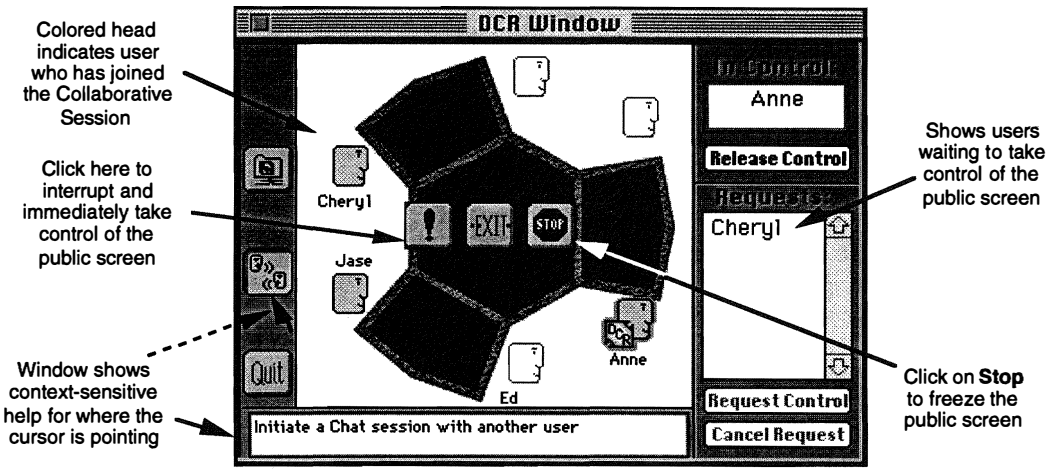

Figure 2. CN interface window during a collaboration.

In the DCR environment, the group focus hovers across the conference table. Since the public screens are in the table (and not projected on a wall), electronic information is more like paper on the table. Team members can transfer their attention between teammates and other forms of information with minimal physical movement. This arrangement alters what would tend to be a presentation in a traditional meeting to a group discussion.

Students who have not taken part in teamwork before may be apprehensive. However, a brief training session and the synergy of multiple media, used with effective protocols, overcomes this. The ability to control media through various well-defined protocols gives each team member greater opportunity to be "heard," spawns creativity, increases mutual understanding, and results in a greater sense of team ownership.

7. A Study of DCR and NonDCR Teams

Data on two undergraduate teams working on the same projects for the same course (Software Design & Documentation, Spring 1995) have been gathered and are being analyzed. One team used the DCR, the other did not. Baseline studies of teams from this course and from Rensselaer's Design of Mechanical Systems course have been conducted since 1991. Future studies will include multidisciplinary teams of engineers, architects, managers, and technical writers.

The general research approach is to make observations of progress on projects and processes used by a team. Due to the complexity of design team behavior over time, several methods are used to gather data. Each week activity logs are collected from each student. Logs describe the work they have done in relation to the assigned projects, including individual, subgroup, and team work. An observer attends, takes notes, and tape records each team meeting. In a DCR session, an event log (including occasional public screen dumps) is also kept automatically. The team observer conducts team member interviews and each member assesses team and co-worker performance twice.

Transcripts from all sources must be synchronized so that critical transitions in team thinking and behavior can be identified. The number of issues discussed, ideas generated, topical shifts in discussions, participation levels of group members, the amount of time spent discussing topics, the quality of the design process, and the quality of the final design are measured.

A second phase of the research is a study of how protocols for media resource control affect team behavior and work product. Due to the unpredictability of how team members will interact at any given meeting, the protocols, whether formal or informal, must be flexible. The ability to adapt protocols for the task at hand should increase the effectiveness of communication.

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