Exploring Collaborative Learning in Rensselaer's Classroom-in-the-Round

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ABSTRACT

This paper describes several aspects of our on-going research relating to technologies and techniques for collaborative learning. Our research is focused on the classroom-in-the-round, a CSCW enabled classroom that attempts to promote collaborative learning through novel room design, hardware, software and courseware. Encouraging preliminary feedback from courses we are teaching in the classroom is presented. An in-depth study conducted to evaluate the effectiveness of assigned roles on collaboration between pairs of users in a synchronous groupware simulation is then discussed. Statistically significant results show that assigned roles increase team interaction and improve group performance in subsequent unrelated group activities, when compared to a control group. The paper closes with some remarks on promising instructional techniques we are investigating for collaborative learning, including distributed grading, on-line presentation of team projects, and team-oriented presentation-style exams.

Keywords

collaborative learning, synchronous groupware, assigned roles, classroom-in-the-round

INTRODUCTION

Intellectual teamwork, in which student teams share knowledge and collaborate on projects and assignments, has emerged as a major instructional technique at many colleges and universities. To foster intellectual teamwork, Rensselaer Polytechnic Institute has initiated "studio format" classes that stress technological support for instruction and student collaboration [1]. In addition to several technology-enhanced classrooms with workstations and advanced projection systems, a unique, conference-style facility known as the "classroom-in-the-round", illustrated in Figure 2, features a novel circular room design coupled with special furniture, hardware, software and courseware intended to enhance collaboration [2,3]. In this paper we will describe several aspects of our research relating to technologies and techniques for collaborative learning, all of which focus on this special classroom.

THE CLASSROOM-IN-THE-ROUND

The most striking features of the classroom-in-the-round are its eight technology enhanced "tulip-shaped" conference tables (see Figure 1), which merge the ergonomic seating of a conference room with the traditional podium centered lecture hall. Each of these tables provides seating for 2-6 students, with a single Windows PC that can be controlled from two separate keyboards and mice. Two large screen color monitors are connected to the PC and buried in the table, so as to afford a completely flat work surface while at the same time preserving the natural lines of sight. This allows users to talk freely with one another, and also to enjoy an unobstructed view of the entire classroom. At the front of the room, the instructor's podium also houses a Windows PC, as well as a high-end projection system that can display the podium PC's screen or the image from a document camera. In addition, there is a SoftBoard[TM] interactive electronic whiteboard that can record and display whatever is written or drawn upon it.

Figure 1: Tulip-shaped conference tables

Figure 2: Rensselaer's classroom-in-the-round

The design of the classroom naturally divides the class into teams, where each student can control the computer embedded in the conference table through dual controls. The computers are equipped with an array of software packages including various web browsers, word processors, and presentation composers. Hummingbird Communication's Exceed™ supports connection to Unix workstations, allowing students use of all X-Windows based software provided on the campus-wide network. Using Netopia's Timbuktu Pro™ the instructor can connect to any table's computer and project that team's work to the entire class. In addition, students can connect to the podium computer and directly view the instructor's presentation material on their local table computer. By displaying the students' desktops using the projector, the instructor can critique work for the benefit of the class as a whole. Similarly, students can connect to other conference table computers and share work among teams.

Ethernet and floppy drives allow students to move material previously generated on an outside computer to any of the team computers in the classroom. Laptop computers can connect via Ethernet ports to the table computers, providing students with public and private workspaces. During team meetings, the instructor can move through the classroom watching the conference table monitors and can take control of the team's computer to illustrate a concept or demonstrate a technique.

CS-I IN THE CLASSROOM-IN-THE-ROUND

Computer Science I is the standard introductory computer science course taken by almost all undergraduates at Rensselaer. Students learn basic Unix tools, HTML, the procedural part of C++ (object oriented material is covered in Computer Science II), and a variety of fundamental concepts and programming techniques (e.g. recursion). The course consists of five contact hours per week: two 50-minute lectures in large halls plus a 3-hour lab where up to 30 students at a time are given individual instruction by teams of three or more teaching assistants (mixed graduate and undergraduate).

Two experimental lab sections of Computer Science I were taught during Spring '98 semester in the classroom-in-the-round by the third author (Lim). Each week students worked collaboratively on a specially designed problem set that consisted of a series of 1-, 5- and 10-point questions from which students were required to answer a total of 50 points. The difficulty and scope of each problem determined its point value. 1-point questions were often multiple choice or definition-type questions. 5-point questions required a paragraph or, in the case of programming, 5-10 lines of code. 10-point questions were typically larger scale programming problems. This allowed each team to select a set of problems that would benefit all members, novices and experts alike.

Team members worked together to select their questions with the help of a web-based server which employed a CGI script that allowed each team to select a set of questions by filling out a form with radio buttons next to the question description. The server then electronically mailed a copy of the question to all team members. Students were encouraged to cooperatively select a customized problem set. Once the formatted problem set had been mailed to the students, they could print out a hardcopy and begin working at the conference tables. Students were encouraged to share expertise with their teammates in the process of formulating their individual responses.

One initial concern was that a single expert student would dominate the selection of problems, choosing problems beyond the skill level of novice teammates. Our hope was that the classroom-in-the-round would facilitate team cooperation both by providing a more ergonomic configuration for group work and by limiting computer control by a particular individual through the use of the dual computer controls. To find out if this was the case, we administered a preliminary survey to the students in the collaborative classroom and also to students in a traditional lab in which all of the students sat in rooms, each at his/her own workstation, facing the front of the room. Each student was asked to evaluate the statement, "*The groups that you work with tend to be dominated by a single individual*" using a numeric response ranging from 1 (strongly agree) to 5 (strongly disagree). Table 1 shows the response from students in the two different classrooms where N is the number of students surveyed, x is the mean value of the numeric response, and s is the standard deviation.

Group	N	x	s
Classroom-in-the-Round	28	3.607	0.786
Traditional Classroom	38	2.947	1.064

Table 1: Responses from survey question: "*The groups that you work with tend to be dominated by a single individual?*"

A lower mean value for the traditional lab indicates that the students tend to agree more with the statement that an individual dominated the group work. Another part of the preliminary survey asked students to identify which characteristics of the classroom-in-the-round were most useful for conducting group work. Four features of the conference tables were informally evaluated using the same numeric rating system. Table 2 shows the results for the questions. These preliminary findings will be used to formulate a more thorough survey.

Features N = 29	x	s
1. Embedded monitor	2.207	0.940
2. Shared computing environment	2.207	1.048
3. Shared monitor	2.103	1.081
4. Tulip configuration	2.448	0.910

Table 2: Survey responses from classroom-in-the-round

ASSIGNED ROLES STUDY

The hardware, software, and architecture of the classroom-in-the-round provide a basic infrastructure for collaboration. Preliminary results from the student surveys discussed above indicate positive feelings about its use in an instructional setting. Nevertheless, team breakdowns have been observed during lab sessions. A combination of new teaching techniques and software tools that incorporate the basic classroom infrastructure may reduce the frequency or severity of such breakdowns.

One technique we have been experimenting with is assigned roles within a team. Instead of dividing a task into smaller independent subtasks to be completed in parallel, team members are assigned different but complementary roles for completing a shared task. Our hypothesis is that explicitly assigned roles can induce stronger collaboration among team members. To test the hypothesis, the first author (Dugan) developed a synchronous collaborative simulation called CollabBillboard.

CollabBillBoard Architecture

CollabBillboard is a synchronous face-to-face two player simulation that attempts to address some shortcomings of previous multiuser simulations through explicitly assigned roles and group evaluation. Assigned roles require each user to take on a specific role during the simulation. These roles are complementary, but non-overlapping. Both users must cooperate within their roles in order to achieve the simulation goal. Group evaluation, rather than individual based, uses team based performance criteria.
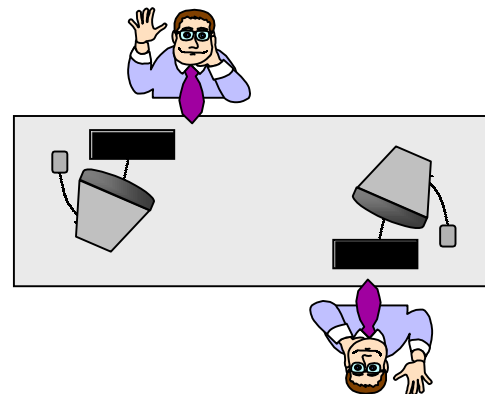
The CollabBillboard application is designed for networked personal computers running Windows 95 or NT. The development environment, Microsoft Visual C++ (VC++), was augmented with: Microsoft Foundation Classes (MFC) for GUI support, DirectX for high performance graphics, and Winsock for communication.

The system requires one machine per user. The complete simulation state is replicated on each machine. Participants can, in theory, be situated at different physical locations. However, the game is designed with activities that require high bandwidth communication between participants. For this reason, a face-to-face experimental setup was used.

Experimental Method

A study was conducted by the first author to evaluate the effect CollabBillboard might have on collaboration between pairs of users. The study used two versions of the program, one with and another without assigned roles. Time to completion, percent of time spent conversing, and accurate billboard placement were some performance criteria measured. Subjects were then given a paper and pencil collaborative exercise. The results of this exercise were compared against a solution key. Finally, the subjects were given a survey to complete that allowed them to express their subjective feelings about the simulation, and about collaborative experiences during the session.

A long desk with monitors at opposite ends was set up in an office. Users sat on different sides of the desk, each in front of a monitor. The monitors were set up so that each could be seen only by the user in front of it, and were angled so that both users would sit between a three foot gap between the monitors on the table; this arrangement afforded line-of-site viewing for non-verbal communication (see Figure 3).

Figure 3: Sketch of the experimental setup

Participants
Research participants were thirty two students at a medium sized northeastern engineering university. Subjects were predominantly male graduate students. All were volunteers solicited via e-mail or a brief presentation in several advanced computer science courses.

Task Overview
Research participants worked on one of two versions of the CollabBillboard simulation. One version of the simulation used assigned roles, while the other (the control) did not. Participants were grouped into pairs, with each pair using one version of CollabBillboard. When the simulation was completed, participants worked through a classic paper and

pencil collaborative exercise called Lost At Sea [4]. At the end of the experiment, the pair were asked to complete a survey about their experiences.

Pairs of participants were scheduled for a one hour session. When they arrived, they were introduced to each other, the tasks to be performed were explained, and they were asked to sign a consent form. A tape recorder was started to record the audio exchange during the CollabBillBoard portion of the session. Participants started the CollabBillBoard application on their respective machines. When network communication was established, one of the users pressed the OK button on the initial dialog window, and both users were presented with a task menu.

The session moderator explained that the participants were part of a fictitious advertising company that wanted to place a billboard in the city of Boston. Two major tasks were needed to complete the application: select a site in the city to place the billboard; assemble the scrambled pieces of the billboard on the site's billboard frame.
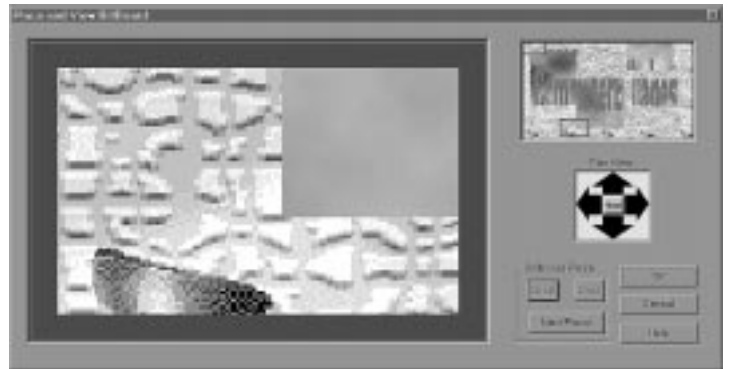
The first task, Site Selection, brought up a shared map of the city of Boston, Massachusetts (see Figure 4). Telepointers were used to indicate remote user focus on the map. As users moved over possible sites, an informational window appeared describing the site. When a site was selected, it was highlighted. These actions appeared on both participant's maps, with separate colors indicating a local or remote action. Once participants selected a site, they proceeded to the second task.

Figure 4: Selecting a billboard site in the city.

The second task, Billboard Assembly, involved assembling randomly placed pieces of the billboard in the correct order and properly centering them on a billboard frame. At this point, the assigned roles and control versions of the program diverged. The control version brought up a shared billboard frame that users could add billboard pieces to. Each new piece appeared simultaneously in the same random location on both participants' screens (see Figure 5). Participants could grab and move any piece of the billboard at any time. The frame contained a green box representing the local user's position in the frame. A red box represented the remote user's position. To move a billboard piece, a user placed the green box on a billboard
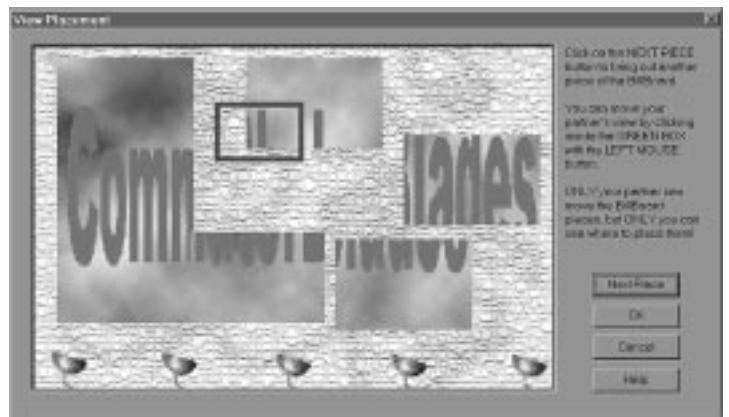
piece, selected the grab button, then used the directional arrows. A zoom window was included for fine grained piece movement.

Figure 5: Control window for assembling billboard. Both users see the same window, view the entire billboard frame and move pieces.

The assigned roles version of the program split the billboard piece assembly into separate subtasks: View Placement and Place Billboard. The View Placement task presented the user with a zoomed out view of the billboard frame. This user could see all billboard pieces and a green box, which represented the Place Billboard user's view. The View Placement user could add new pieces to the frame, and move the other user's view. However, the View user could not move a billboard piece even if the Place user was currently grabbing one (see Figure 6).

The Place Billboard task presented the user with a zoomed in section of the billboard frame. The Place Billboard user could navigate around the billboard frame using the dialog's arrow widget. The user could also grab, move, and drop billboard pieces (see Figure 7).

Figure 6: Assigned roles "view billboard" window. This user has a zoomed out view of the billboard frame but cannot move any pieces.

Complications arose with assigned roles because neither user could complete the simulation goal independently. The Place Billboard subtask had a view that represented a small portion of the billboard frame (approximately 1/4 of a billboard piece). This view could be very disorienting. The View Placement task had a good view of the frame, but did

not allow the user to move billboard pieces. As a result, both users depended on each other to complete the billboard assembly.

Once the Billboard had been assembled in either the control or assigned roles version of the program, the team received a score based on four factors: choice of billboard site, properly assembled billboard, properly centered billboard, and time to completion. A brief discussion about the score with the moderator then ensued. At this point the tape recorder was turned off.

Figure 7: Assigned roles "place billboard" window. This user has a zoomed in view of the billboard frame and can move pieces.

The second part of the session involved a classic paper and pencil collaborative exercise called Lost At Sea. Participants were told to read a brief scenario where they imagined themselves on a sinking ship. They had to rank 15 items in the order that they would be taken because the ship might sink at any moment. After the task was completed, the moderator discussed the US Merchant Marine's ranking of the same items.

The final activity of the session was a survey. The survey covered three areas: subjective feelings about CollabBillboard, subjective feelings about collaboration during the session, and personal information. When the survey was completed, the participants were debriefed by the moderator.

Evaluation of Team Performance
Team performance was determined using measurements depending on the stage of the session. For the CollabBillboard stage, five team measurements were used: choice of billboard site, properly assembled billboard, properly centered billboard, time to completion, and conversation as a percentage of task completion time.

For the Lost at Sea stage, 17 team measurements were made. The first 15 were absolute values of the difference between the correct ranking for each item and the team's ranking of the item. Next was a cumulative sum of these deltas. Finally, time to complete the stage was measured.

For the exit survey stage, 31 questions were asked to subjectively assess CollabBillboard and collaborative experiences during the session. Most of these questions used a rating scale from one to five, with lower numbers representing a more positive feeling about the question and higher numbers indicating a negative feeling. A "no opinion" option was available for each question.

Variables
The survey included a personal information section that gathered data about each participant. The information was used to discount measurements because of unique characteristics of a team or individual. Questions covered computer and computer game usage, class in school, full-time/part-time status, and familiarity with partner.

Data Analysis
Fifty three measurements were taken of each team that participated in the study. The results were separated into two groups: assigned roles and control. Team and individual means for each measurement were calculated for both groups.

Sample sizes varied by measurement for various reasons (see Table 3). For example, early problems with audio equipment reduced the number of conversations that could be recorded. Some subjects were already familiar with the Lost at Sea scenario and had to be given a different, but comparable exercise. Finally, some measurements applied to the entire team, while others applied to individuals.

Measurement	Assigned roles Sample Size (N_{ar})	Control Sample Size (N_c)
CollabBillboard	10	6
Conversation	5	4
Lost at Sea	7	6
Exit Survey	20	12

Table 3: Study sample sizes

A *t-test* was performed on the sample means to determine if differences between the roles and control groups were statistically significant The t-test is used when comparing the means of two population groups measured against the same characteristic, but with different sample sizes. The procedure is relatively straightforward. First each group's sample means, standard deviations, and mean difference are calculated. Then a standard deviation of the mean difference between groups is computed. This is used to calculate *v*, the effective number of degrees of freedom, which takes the sample sizes of both groups into account. Finally, a confidence interval is computed. If the interval spans zero, the mean difference between the groups is not considered statistically significant [5].

Statistically significant mean differences were marked as potentially interesting. Other measurements whose mean differences were not significant were also marked if they

seemed relevant to collaboration. An interpretation of the results was then performed.

Results and Analysis

The results are explained and analyzed in the order that they were collected during experiment sessions. The tables presented in this section use a special notation. The *Measurement* column contains descriptions of measurements taken during the experiment. N_{ar} and N_c indicate the assigned roles and control group sample sizes for the values that appear in the table. x_{ar} and s_{ar} are the mean and standard deviation for the assigned roles group. x_c and s_c are the same values for the control group. *Conf. Int.* is the t-test confidence interval. This represents the level of confidence that the assigned roles and control group means for the measurement are statistically different. A *** in this column indicates no significant difference.

CollabBillboard Application

As explained above, the CollabBillboard stage of the experiment measured performance using five characteristics. *Pieces In Order* (see Table 4) measured the quality of the billboard assembly. It represents the number of pixels off each billboard piece was from its neighbors. If each piece was next to its correct neighbor, then the team received a score of zero. Higher scores indicated a lower quality assembly.

Measurement $N_{ar} = 10, N_c=6$	x_{ar}	s_{ar}	x_c	s_c	Conf. Int.
Pieces in Order (pixels)	0	0	23.3	36.7	80%
Time to Completion (seconds)	1567	297.8	1156.8	193.7	90%

Table 4: CollabBillboard measurements

Time to Completion (see Table 4) measured how much time it took the team to complete the entire simulation. It took the assigned roles group almost seven minutes longer to complete. The reasons for this time difference are straightforward. The control group was able to assemble the billboard in parallel, because both participants had access to the move piece function. In the assigned roles group, only one participant was able to move pieces. The process of figuring out where pieces should be placed was also easier for the control group. Both participants could see the entire billboard frame, which allowed them to quickly decide where pieces belonged. With the assigned roles group, only the participant with the View Placement dialog could view of the entire billboard frame. This forced both participants into a verbal dialogue to move pieces to their proper place in the frame. Note that although it took longer for the assigned roles group to complete the assembly task, the quality of the result was higher.

While the team was using CollabBillboard, their conversation was recorded for later analysis. The analysis developed a ratio of time spent in conversation over total task time. This ratio indicated the amount of time, as a percentage, that the team spent in conversation while performing the task. Ratios were calculated for the simulation's two major tasks: Site Selection and Billboard Assembly (see Table 5).

Site Selection conversation ratio was just over 70% for both groups, with no significant difference between the means. There shouldn't be a difference between groups because the task was exactly the same for both groups, and was the first activity performed during the session. The similarity of the ratios is evidence of the population homogeneity between groups.

Billboard Assembly conversation ratio showed a significant difference between groups. Assigned roles teams were involved in conversation 85% of the time. The amount of conversation is not surprising because the Place Billboard participant had to rely on the View Placement participant's verbal directions to place a piece properly on the frame. If no conversation took place, it would have been impossible to assemble the billboard correctly.

The control teams were involved in conversation only 44% of the time. Again, this was not surprising because neither participant needed the other in order to complete the assembly task. Both participants had a full view of the billboard frame, and a move piece capability.

Measurement $N_{ar} = 5, N_c=4$	x_{ar}	s_{ar}	x_c	s_c	Conf. Int.
Site Selection Conversation/Total Time (seconds)	0.7304	0.0745	0.7160	0.1603	***
Billboard Assembly Conversation/ Total Time (seconds)	0.8503	0.0624	0.4444	0.0989	90%

Table 5: Conversation measurements

Lost at Sea Exercise

As previously mentioned, The Lost at Sea exercise measured performance using 17 characteristics. Many of the characteristic means were statistically different between groups; however, the most meaningful measurements were the *Average Delta from Correct Ranking* and *Time to Completion* (see Table 6).

The *Mean Delta from Correct Ranking* was calculated in three stages. First, the absolute value of the difference between a team's ranking for each item and the correct ranking of the item was determined. For example, if the team gave the Sextant a rank of 10 and the correct ranking was 15, then the item's delta value would be 5. Next a mean delta was calculated for each team. Finally a mean delta was calculated for both groups. The smaller the delta value, the better the items were ranked. The assigned roles group performed almost a full rank better on average than the control group in this exercise.

Time to Completion measured the number of seconds it took for the team to complete the Lost at Sea exercise. The

assigned roles group completed the exercise a full five minutes faster on average than the control group.

Measurement N_{ar} = 7, N_c=6	x_{ar}	s_{ar}	x_c	s_c	Conf. Int.
Mean Delta from Correct Ranking	3.295	0.6959	4.089	0.830	90%
Time to Completion (seconds)	1118	148.19	1420	432.11	80%

Table 6: Lost at Sea exercise measurements

Exit Survey
The exit survey asked each participant 26 subjective questions about the CollabBillboard application and the collaborative experience during the session. The response means for the majority of the questions showed no significant variance. However, there were several responses that were statistically different (see Table 7).

Measurement N_{ar} = 20, N_c=12	x_{ar}	s_{ar}	x_c	s_c	Conf. Int.
Cooperative/Independent	1.263	0.4524	2.167	0.9374	90%
Easier by Self?	1.684	1.376	3.333	0.9847	90%
Try other Simulations?	1.737	0.6534	2.273	1.191	80%
Satisfactory Outcome	1.684	0.5824	2.083	0.7930	80%
Goal Directed Behavior	1.389	0.5016	1.833	0.9374	80%
Good Leadership	2.267	0.4577	3.000	0.7560	90%
Prefer CollabBillboard or Lost at Sea?	2.737	1.147	2.917	1.621	***

Table 7: Exit survey measurements

Cooperative/Independent asked if the participant felt interaction in the CollabBillboard application was more cooperative or more independent. A value more towards one indicated a feeling of cooperation. A value towards five indicated a feeling of independence. The assigned roles group scored almost a full point (20%) closer feeling of cooperation.

Goal Directed Behavior asked if the participant felt that the team acted in an organized, productive manner when completing tasks during the session. A value towards one indicated more organization while a value towards five indicated less organization. The assigned roles group scored a half point (10%) greater feeling of organization.

Good Leadership asked when someone took on a leadership role during the session, was the leader effective? A value towards one indicated good leadership, while a value towards 5 indicated poor leadership. The assigned roles group scored 0.75 point (15%) higher feeling about good leadership.

Easier by Self asked if the participant felt it would have been easier to complete the CollabBillboard simulation without a partner. A value towards one indicated a greater desire to work independently while a value towards five indicated a desire to work with a partner. The control

group scored a 1.7 point (33%) higher desire to work cooperatively than the assigned roles group. It is interesting to note that although the assigned roles teams found it more difficult to assemble the billboard, and it took significantly more time, they did a higher quality job.

Satisfactory Outcome asked if the participant felt that the work the team performed during the session was satisfactory. A value towards one indicated a high level of satisfaction, while a value towards five indicated a lower satisfaction. The assigned roles group scored a half point (10%) higher feeling of satisfaction with the team's performance.

Try other Simulations solicited the participant's desire to try other simulations like CollabBillboard. A value towards one indicated a greater willingness to try other simulations while a value towards five indicated less desire. The assigned roles group scored a half point (10%) greater desire to try similar simulations.

Prefer CollabBillboard or Lost at Sea asked which collaborative exercise the participant preferred. A value towards one indicated a preference for CollabBillboard while a value towards five indicated a preference for Lost at Sea. Both groups seemed to be neutral in their feelings about the best exercise with no significant difference between the means.

There were statistically significant differences between groups in almost all of the variables that measured personal characteristics (see Table 8). Both groups used the computer for work a significant number of hours during the week. However, the control group used the computer 10 hours a week more on average for work activities. The assigned roles group used the computer more during the week for games, and during the month for multiuser games.

Measurement N_{ar} = 20, N_c=12	x_{ar}	s_{ar}	x_c	s_c	Conf. Int.
Computer Work (Hrs/Week)	25.105	13.334	38.182	21.43	90%
Computer Recreation (Hrs/Week)	18.052	14.014	10.250	8.080	90%
Multiuser Computer Games (Hrs/Month)	12.368	11.427	1.5	3.605	90%
Class in School	4.833	1.339	5.75	0.6216	90%
Friend Level of Partner	2.263	1.368	2.833	1.528	***

Table 8: Personal information measurements

Class in School recorded the participant's current class as an undergraduate (1=Freshman … 4=Senior), or graduate (5=Master's, 6=Doctorate). The assigned roles group was made up of predominantly Master's students, while the control group was mostly Doctoral students.

Friend Level of Partner recorded the participant's relationship to the other team member. A value of one indicated they had never met, while a value of five indicated they were best friends. In both groups, the team

members tended to be acquaintances, rather than strangers or close friends.

Discussion

We know of no other work that has been done to evaluate collaboration with roles in synchronous groupware, although we are aware of a number of CSCW systems that advocate and include role functionality. Quilt [6] is a collaborative document system that allows users to take on various roles (e.g. writer, commenter, reviewer) during the editing process. These roles restrict read/write access to the document. Share [7] is a customizable shared window synchronous groupware system that allows different members of a group to modify its behavior depending on accessibility, user role, and group work needs.

Intermezzo [8] is a collaborative session management system that uses roles for flexible runtime session, application, and object access control. GroupIE [9] is a groupware toolkit that incorporates roles in a teamwork model that is a fundamental part of the toolkit's framework. A number of other systems have support for roles including: ICICLE [10], a code inspection system, and SUITE [11] a groupware toolkit. Although these systems advocate roles as a powerful collaborative tool, we are not aware of any formal evaluation of the approach's efficacy.

SharedARK is a system for creating synchronous, shared microworlds [12]. A SharedARK microworld is an infinite, shared, two-dimensional "flatland" with a small portion visible on any one computer display. Users manipulate objects using a special mouse driven hand. The system can operate in face-to-face and distance environments. When users encounter each other in SharedARK they can set up audio/video links. A basic model of the physical world is built into the system. Users can experiment and create objects that have mass, density, and momentum.

Several applications have been created including the Puckland [13] simulator for elastic collisions and ARKCola [14], a simulation of a soft drink processing plant. Experiments with SharedARK systems have shown that students are more engaged and perform deeper evaluations of problem sets than they do with paper and pencil exercises [12]. TurboTurtle [15] is a system for exploring Newtonian physics, similar to SharedARK. A distinguishing feature of the system is its sophisticated support for awareness of other users including user lists, telepointers, and shared widget controls.

The results and analysis of our study support the hypothesis that assigned roles can improve collaboration both during the simulation and in subsequent group activities. Although it took longer for the assigned roles group to complete the simulation, they produced higher quality results indicating more effective collaboration. Conversation, another measure of collaboration, occurred during 85% of the assembly task for assigned roles and only 44% of the assembly task for the control. On the second collaborative activity, the assigned roles group completed the work in less time with superior results. In every instance that the exit survey had statistically valid mean differences, the responses were more positive about collaboration in the assigned roles group.

One anomaly, the *Easier by Self* question, showed that assigned roles participants felt it would have been easier to complete the simulation without a partner. This would have involved allowing both the View Placement and Place Billboard functions to be executed by a single participant. This intuition might have been validated by the more cooperative feelings the control group had for this question. The control group had both functions integrated into a single dialog window accessed by both participants.

The variables measured in the study offered mixed conclusions. The control group used the computer 10 hours a week more for work, and were pursuing a more advanced degree. Presumably this might have given them an edge in the use of the simulation, and also caused them to perform better on the paper and pencil exercise. The assigned roles group used the computer more for games, and were pursuing a less advanced degree. This might have given them an edge in the simulation, but probably not on the paper and pencil exercise. Better collaboration due to a previous relationship between members of a team can be ruled out in both groups because in general team members tended to be acquaintances, but not close friends.

Several limitations of the study should be mentioned. The roles imposed by the assigned roles version of the program sometimes created frustration in the team. This was particularly true for the Place Billboard partner. Recall that this subtask involved moving the billboard pieces under the other partner's direction. The Place Billboard participant sometimes felt like an extension of the View Placement participant's hand rather than an equal partner. Positive feelings about cooperation might have been improved if a better subtask balance had been established.

Although CollabBillboard is a fully networked, distributed application, the ability to work in parallel was only utilized in the control version, where both participants were able to assemble billboard pieces at the same time. Assigned roles serialized the assembly process. The View Placement participant could only give verbal directions while a piece was being moved by the Place Billboard participant. The task of assembling the billboard might have been accelerated if a more parallel version of the process had been developed for the assigned roles group.

Personal information recorded in the exit survey indicated statistically significant differences between the assigned roles and control groups. Although these differences indicated the control group should have performed better on the exercises, the assigned roles group actually had superior performance. Despite this finding, the results of the study

would have had more validity if there were no significant differences between the variable means recorded .

WORK IN PROGRESS
Another aspect of our research efforts based on the classroom-in-the-round involves the second author (Breimer), who is investigating evaluation of student work through distributed grading techniques, online presentation of team projects, and team-oriented presentation style exams. These techniques are being implemented in the Graph Theory course for upper level undergraduates taught by the fifth author (Goldberg).

Distributed Grading and On-line Team Presentations
We have found that a distributed grading system appears to motivate students to collaborate closely in teams, while simultaneously providing a structure for designing effective collaborative activities. During the first week of the term, students are encouraged to work on classroom activities and problems with the other students who happen to share their table in the classroom-in-the-round. This allows the students to meet and interact in a natural fashion. When team projects are then assigned, the students tend to split up according to where they are seated, without any need for instructor intervention.

For each assignment, a team is assigned a single common problem towards the solution of which all members are required to contribute. In addition, each student is allowed to select two individual problems from a set of twenty questions. Students are given the grading specifications in advance. 50% of each individual's grade is determined by the team score on the common problem, 30% is determined by his/her performance on the selected individual problems, and the remaining 20% is determined by the average scores of the teammates on their individual problems.

$$grade = 0.5 * g_{common} + 0.3 * g_{indiv} + 0.2 * g_{average}$$

This formula provides a compromise between individual grading and strict group grading. It attempts to minimize the team penalty due to poor performance by any individual member, while preserving an incentive for monitoring and critiquing individual team members. The common problem is an unrestricted collaborative exercise. Team members have total autonomy to decide how the workload for the common problem will be split up. The individual problems, on the other hand, serve as explicitly divided collaborative exercises, in the sense that each individual is assigned specific problems but students are permitted (indeed, encouraged) to share information and collaboratively work on refining their unified submission.

Team projects are submitted as on-line HTML presentations. WebCT [16] is used to provide the students with tools for uploading and designing their presentations. Netscape Composer and Microsoft Word serve as the primary web authoring tools. We find on-line presentations useful, because they allow students to study and analyze each other's work.

Team-oriented Presentation-style Exams
The second exam during the Spring '98 semester was implemented as a multi-session, team-oriented classroom activity. Students were asked to divide up into teams of size 3-4. Questions were asked each day during lecture. Teams were given 5-15 minutes to discuss each question and formulate a response, after which a student was selected at random by the instructor to present the team's solution to the class. The instructor evaluated the team's solution as presented by the spokesperson, and a score from 1 to 10 was assigned to all team members.

Because students were selected at random, it was important for a team to ensure that every member understood the joint solution. If a student could not obtain the maximum score of 10 points, the question was opened up to the other teams. Another team could gain the remaining points by providing an alternative solution, by correcting errors in the previous team's solution, or by extending that solution, as appropriate. This process would continue until a maximum of 10 points had been awarded for the given problem or until every team had a chance to contribute to the solution. In all cases, the grade given to a presenter was applied to all members of the presenter's team.

The instructor selected the questions but students were notified of the topics in advance. By grading the team based on an individual's response, our hope was to encourage team members to share expertise with one another, and thereby to enhance the entire team's performance. We believe that the conference tables in the classroom-in-the-round provided students with an enhanced seating arrangement for discussions and for composition of computer-based presentation materials, and that this activity would have been difficult to implement using a conventional, lecture-style classroom.

CONCLUSION
We have described initial findings relating to a variety of undergraduate courses being taught in a unique facility at Rensselaer Polytechnic Institute known as the classroom-in-the-round. In particular, we have described a study conducted to evaluate the effectiveness of assigned roles on collaboration between pairs of users in a synchronous groupware simulation. Statistically significant results show that assigned roles increased team interaction and improved group performance in subsequent unrelated group activities when compared to a control group. The promising results of the study and the flexibility of CollabBillboard's architecture should allow us to use it to explore additional aspects of team organization and collaboration (e.g., in a distance learning setting, whether competition between teams may improve within-team performance, and how best to organize larger teams).

ON-LINE AVAILIBILITY OF MATERIALS
A copy of CollabBillboard, the Lost at Sea exercise, and the exit survey can be downloaded from the following web address: http://www.cs.rpi.edu/~dugan/collabbilboard.html

Applications developed with VC++ and MFC have a structure oriented around the user interface. Each dialog is associated with a C++ class. Events generated by widgets in the dialog are converted to messages that invoke class methods. To enable multiuser capabilities, CollabBillboard includes a shadow socket class with each dialog. The socket shadow contains methods for communication setup/takedown, sending special events, and receiving special events. Send event methods report local events and data that are of interest to remote users. The receive event method converts remote user messages to a local event and data format. Figure 8 depicts the socket shadow class for the initial dialog panel. The member functions OnAccept and OnConnect are invoked during communication setup/takedown. SendOK is invoked by the dialog class method ButtonOK that is invoked when the user presses the OK button. OnReceive is invoked when a remote message arrives. For this dialog, OnReceive gets remote ButtonOK events and invokes same local dialog method.

```
Class CcollabBillBoardDlgSocket : public
        CollabBillBoardSocket
{
private:
        void OnAccept(int theErrorCode);
        void OnConnect(int theErrorCode);
        void OnReceive(int theErrorCode);
public:
        BOOL InitializeSockets();
        BOOL SendOK();
};
```

Figure 8: CollabBillboard socket shadow class

REFERENCES
1. Hammonds, K.H., *et al.*, *The New U: A Tough Market is Reshaping Colleges*, Business Week, p. 96-102, December 22, 1997.

2. Ferraro, A., E. Rogers, and C. Geisler, *Team Learning Through Computer Supported Collaborative Design*, in *Proceedings of Computer Support for Collaborative Learning, CSCL '95*, 1995: p. 120-124.

3. Rogers, E.H. and C. Geisler, *A Collaborative Learning Environment for Intellectual Teamwork Across the Curriculum*, in *Proceedings of Frontiers in Education*, 1997, Pittsburgh: p. CD-Paper 1491.

4. Gamble, T.K. and M. Gamble, *Communication Works*, Fourth ed., 1993: McGraw-Hill.

5. Jain, R., *The Art of Computer Systems Performance Analysis*, 1991, New York: John Wiley and Sons, 685.

6. Leland, M.D.P., R.S. Fish, and R.E. Kraut, *Collaborative document production using Quilt*, in *Proceedings of the ACM Conference on Computer-Supported Cooperative Work (CSCW '88)*, 1988, Portland, Oregon: ACM Press: p. 206-215.

7. Greenberg, S., *Personalizable groupware: Accommodating individual roles and group differences*, in *Proceedings of European Conference of Computer Supported Cooperative Work (ECSCW '91)*, 1991, Amsterdam: ACM Press

8. Edwards, W.K., *Policies and roles in collaborative applications*, in *Proceedings of ACM Conference on Computer Supported Cooperative Work (CSCW '96)*, 1996, New York: ACM Press: p. 11-20.

9. Urnes, T. and R. Nejabi, *Tools for Implementing Groupware: Survey and Evaluation*, Department of Computer Science, York University, 1994, Technical Report, CS-94-03.

10. Brothers, L., V. Sembugamoorthy, and M. Muller, *ICICLE: Groupware for Code Inspection*, in *Proceedings of ACM Conference on Computer-Supported Cooperative Work (CSCW '90)*, 1990: ACM Press: p. 169-181.

11. Dewan, P. and R. Choudhary, *A High-Level and Flexible Framework for Implementing Multiuser User Interfaces*, ACM Transactions on Information Systems, 1992, 10(4): p. 346-380.

12. Taylor, J., *et al.*, *Discourse and Harmony: Preliminary Findings in a Case-Study of Multi-Media Collaborative Problem Solving*, Open University, April 1991, Programme on Learner Use of Media, No. 7.

13. Whitelock, D., *et al.*, *Investigating the Role of Socio-Cognitive Conflict in Computer Supported Learning about Elastic Collisions*, Centre for Information Technology in Education, The Open University, September 1992, Technical Report, 169.

14. Gaver, W.W., R.B. Smith, and T. O'Shea, *Effective Sounds in Complex Systems*, in *Proceedings of ACM Conference on Human Factors in Computing Systems (CHI '91)*, 1991: ACM Press: p. 85-97.

15. Cockburn, A. and S. Greenberg, *TurboTurtle: A Collaborative Microworld for Exploring Newtonian Physics*, in *Proceedings of Computer Support for Collaborative Learning, CSCL '95*, 1995, Indiana University: p. 62-66.

16. Goldberg, M.W., *Communication and Collaboration Tools in WebCT*, in *Proceedings of the Conference on Enabling Network-Based Learning*, 1997, Espoo, Finland.