Assessing and supporting remote collaborative problem solving

Mark Schlager and Patricia Schank

SRI International, Menlo Park, CA 94025
(650) 859-2881, (650) 859-3934

ABSTRACT

Distant Mentor is a collaboration/simulation environment to facilitate joint problem solving from a distance. We describe a study designed to demonstrate the ways in which the system can support collaborative learning.

KEYWORDS: collaboration, distance learning, CSCW.

INTRODUCTION

Our work addresses the problem of helping learners develop concepts and skills needed to be productive in the fast-changing technical workplace. We developed a new model of collaborative learning, called *cognitive mentoring* [3]. Our model is based on the idea of individually tailored assistance provided at the learner's request when an impasse is encountered in problem solving. We have studied such interactions in the workplace and developed a synchronous collaboration/simulation software environment that we call *Distant Mentor* (DM) to facilitate mentoring from a distance [4]. In this report, we describe a study designed to demonstrate the ways in which our prototype technology can support cognitive mentoring over a local area network.

Cognitive Mentoring Concepts

Cognitive mentoring can be thought of as joint problem solving involving a more-expert participant (mentor) and less-expert participants (learners). It occurs in the context of actual work and work-related tools rather than in an isolated training environment inhabited by instructional tools. In contrast to tutoring, the mentor doesn't necessarily know the learner's problem or the right answer, but rather uses domain expertise in working jointly with the learner to overcome the impasse. At a gross level, we identified several mentoring stages, including problem definition, problem diagnosis, execution of suggested actions, solution evaluation, and reflection. In practice, movement through these "stages" is not strictly sequential but rather highly recursive. Within each stage, we have identified a number of specific processes (e.g., demonstration, scaffolding) that learners and mentors execute. See [3] for a more detailed description of mentor and learner behaviors in cognitive mentoring.

Distant Mentor Prototype

The system we used to explore networked cognitive mentoring merged two applications developed independently at SRI: an application-independent synchronous collaboration system that integrates voice, gesturing (with pointing devices), and application sharing [2], and a discrete event circuit board manufacturing simulation based on the *Shoptalk* system [1]. *Shoptalk* allows learners to use a combination of natural language and point-and-click gestures to query, rewind, and step through the simulation for information needed to diagnose the cause of manufacturing problems. It also provides a history of prior queries and answers for easy review. The resulting Distant Mentor (DM) prototype allows people in different locations working in a networked UNIX environment to jointly interact with the simulation while maintaining a conversation over the network-based audio channel.

The utility of DM depends on how well mentoring interactions facilitate problem solving. For instance, with the aid of a mentor, do subjects take significantly less time to solve problems? Another interesting measure of the system's utility relates to whether it affords any advantages over a mode of distant collaboration that is used commonly today--the telephone and FAX machine. If mentor/learner pairs are given a version of the system that allows audio communication and the sharing of static screen dumps but no joint interaction with the application, will problem solving be significantly hindered? (We did not compare DM to face-to-face mentoring because we were interested in the quality of assistance possible when people are *not* co-located.)

METHOD

Twelve (paid) San Jose State University Industrial and Systems Engineering students (six women and six men) received training on DM, and then worked alone or with one of two mentors to solve problems. Three conditions were employed, all balanced for gender: 1) *Solo:* Subjects used the system to solve problems independently, without the aid of a mentor. 2) *DM:* Subjects solved problems with the help of a mentor, using the full, joint interactive capability of the system. 3) *FAX:* Subjects had access to the mentor via an audio channel and could send *snapshots* of the current DM screen to the mentor as needed.

Problems

The simulated shop floor and the production problems were designed in cooperation with a professor of industrial engineering at San Jose State University. Our goal was to make the problems authentic and complex enough to challenge even the mentors. In each problem, a simulation had been run with one or more parameters changed from the "normal" run, on which all machines were working properly and all boards had the same priority. Consequently, the boards finished in a different order. For example, one problem read: *A number of boards are extremely late in finishing relative to their normal finishing times. Find them and diagnose the root cause.* Complete problem solutions contained 2-4 parts, and the parameters were varied to ensure that the mentors did not know the problem solution in advance.

Design

In the experimental group, eight subjects worked with one of two mentors to complete a practice problem and two test problems in one session. Four of the subjects solved the first problem in the DM condition the second in the FAX condition. The other four subjects worked in the FAX condition first and DM second. Four control subjects solved both of their problems in the Solo condition. Thus, each condition was represented by eight problems.

Procedure

The mentor sat in a separate room, isolated from the learner except through the network. Mentors were instructed to imagine being the more knowledgeable colleague in a peer relationship. They brought their own real work to the sessions to work on when not involved in mentoring. Mentors were not given any specific instructions as to pedagogy; they were told to respond as they would if asked for help by a colleague in the workplace (i.e., take a problem-centered orientation rather than a tutorial one). Subjects were instructed to contact the mentor for help as needed. When the mentor and learner felt they had the solution, they would consult the experimenter. If the solution was correct and complete, the subject was instructed to go on to the next problem; otherwise, the experimenter would inform the mentor and ask them to continue. When the pair felt they had the solution a second time, the experimenter would ask them to move on whether or not the solution was complete, to avoid frustrating the subjects.

Data Capture and Analyses

Sessions were videotaped, and transcripts of learner-mentor dialogue and actions were coded into our cognitive mentoring stages. We conducted ANOVAs to assess effects of condition on several measures, including solution time, mentoring time and stages, and solution completeness. All reported findings are significant at $p<.05$. See [4] for a more detailed discussion of these (and additional) analyses and observations, such as mentor effects and styles.

Table 1. Measures by condition.

Table 1. Measures by condition.

	DM	FAX	Solo
#Problems fully solved	8[a]	4	5
%Solution	100[a]	75	86
Solution time (min)	35.5[b]	40.0[b]	82.7
#Conferences	2.0	2.2	n/a
Conference time (min)	19	23.1	n/a
%Definition	13	16	n/a
%Diagnosis	43	45	n/a
%Execution	26	26	n/a
%Evaluation	2	2	n/a
%Reflection	16	11	n/a

[a]sig. diff. from FAX, $p<.05$; [b]sig. diff. from Solo, $p<.05$

RESULTS

Solo subjects required about 83 minutes on average to solve a problem, while DM and FAX subjects solved the problems in significantly less time (36 and 40 minutes per problem, respectively; see Table 1). DM subjects solved all problems completely, while FAX solutions were significantly less complete--only half (4) were fully solved (mean completeness was 75%). Solo subjects solved 5 of the 8 problems completely (mean completeness was 86%). No significant differences were found in either the average number of conferences (2) or conference time (21 min.) per problem.

Problem diagnosis represented the largest percentage of mentor-learner interactions (44%), followed by execution (e.g., query entry), problem definition, reflection, and evaluation. Although we predicted that the FAX group would spend a higher proportion of time in the definition stage and less time in reflection, the observed differences were not significant. Had we enforced complete solutions, the observed trends may have reached significance.

DISCUSSION

DM affords significant advantages over both individual and collaborative telephone/FAX problem solving. We attribute the reduced time to solve problems for mentored (compared to unmentored) subjects to the help provided by the mentor. The lack of solution and stage time differences between the FAX and DM groups is partially explained by our decision to ask subjects who had not arrived at a complete solution after two attempts to move on to the next problem--had we allowed them to continue, we believe that differences would have emerged. Results also suggest that although both DM and FAX groups spent a similar amount of time in each mentoring stage, joint interaction with the simulation improves the effectiveness of this time in terms of solution quality. In a post-hoc test of overall problem solving productivity, we summed the mentoring and total solution time and found a significant savings (34%) for the DM subjects only over the Solo group, demonstrating that the overall time savings more than offset the investment of the mentor's time. These results suggest that corporate investment in network-based cognitive mentoring could significantly improve both productivity and quality of distributed teamwork. In our future work, we plan to explore these and other field implementation issues.

ACKNOWLEDGMENTS

We thank Barbara Means, Louis Freund, Chris Hoadley, Jean Liittschwager, and Erik Olsen for their help and suggestions.

REFERENCES

1. Cohen, P., Dalrymple, M., Moran, D., Pereira, F., Sullivan, J., Gargan, R., Schlossberg, J., and Tyler, S. Synergistic use of direct manipulation and natural language. In Proc. CHI '89 Human Factors in Computing Systems (Austin, April 30-May 4, 1989), ACM Press, pp. 227-233.

2. Craighill, E., Lang, R., Fong, M., and Skinner, K. CECED: A system for informal multimedia collaboration. In Proc. ACM MULTIMEDIA 93 Conference (Anaheim, Aug. 1993), Addison-Wesley.

3. Schlager, M, Poirier, C., and Means, B. Mentors in the classroom: Bringing the world outside in. In H. McLellan (Ed.), Situated learning perspectives. Englewood Cliffs, NJ, 1996, pp. 243-261.

4. Schlager, M., Means, B., and Schank, P. Assessing Distant Mentor. SRI International technical report, in prep.