A Computer-Network-Supported Cooperative Distance Learning System for Technical Communication Education
Chien Chou, Member, IEEE, and Chuen-Tsai Sun, Member, IEEE

Abstract—This paper discusses applying computer networks to cooperative distance learning for technical communication education. It first outlines applications of communication technologies employed in distance learning, and describes the design strategies of the applications. The paper's main focus is on the CORAL (Cooperative Remotely Accessible Learning) system for promoting cooperative distance learning currently under development in Taiwan. The CORAL system is a collective and collaborative project intended to integrate four major components in concept and construction: an interactive learning environment, educational foundations and implications, domain knowledge, and research efforts. One of the CORAL system’s goals is to aid science and engineering students in learning communication technology courseware. The CORAL development process, including its design approach, structure, courseware, and evaluation, is reported. Research issues are also addressed.

INTRODUCTION
Advancements in communication technology are changing the way people around the world teach and learn. Communication technology offers new alternatives for creating, storing, accessing, distributing, and sharing learning materials. Since the Internet, Bulletin Board Systems (BBS’s), e-mail, and multimedia have already become parts of most college students’ lives nowadays, applying these new communication technologies to instruction in technical communication is a great challenge for schools, teachers, and researchers in conventional classrooms as well as in distance learning environments. The main focus of this paper is on how computer networks are being used for technical communication education in a cooperative distance learning environment in Taiwan.

Overview of Distance Learning
Distance education or learning has a long history of development under a variety of names (e.g., correspondence study, open learning) and theories (e.g., independence and autonomy, interaction and communication). The basic idea behind distance education is that teachers and learners are apart [1], [2]. If we use the dimensions of time and location of learning, noting whether they are the same or different, four sets of learning situations can be characterized, as shown in Table I. The purpose of distance learning is to overcome the barriers of geographical separation between teachers and learners, as in the lower two sets of learning situations. However, with the recent rapid advances in communication technologies, the upper two sets can be virtually duplicated in distance learning.

Communication Technology Used in Distance Learning
Garrison [3] categorized the communication technologies employed in distance learning, as shown in Table II. The first generation is represented by print. The major information presented in printed matter is text and graphics, and the packages for this information are books, study guides, and newsletters. The delivery method for the printed materials is mail systems (correspondence study). The major type of interaction supported by this generation of technology is learner-content interaction.

The second generation of distance education communication technologies is exemplified by broadcast media: radio, which delivers analog audio, and television, which delivers analog audio as well as visual instructional messages. These messages are usually broadcast over the airwaves or cable systems, and packaged as audio tapes and videotapes. As with printed matter, teachers and students must make special efforts and arrangements to interact with each other.

The third generation depends on microcomputers to deliver instructional materials in digital form. Learning materials can be stored on floppy/removable disks or CD-ROM’s, delivered
TABLE I
GENERATIONS OF TECHNOLOGY USED IN DISTANCE EDUCATION

<table>
<thead>
<tr>
<th>Technology generation</th>
<th>Presentation format</th>
<th>Main package delivery method</th>
<th>Interaction supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Print</td>
<td>Printed text, graphics</td>
<td>Books, study guides, newsletters</td>
<td>Mail system</td>
</tr>
<tr>
<td>Broadcast media</td>
<td>Analog audio, analog video</td>
<td>TV programs/ videotapes, radio programs/audio tapes</td>
<td>Air/cable, mail system</td>
</tr>
<tr>
<td>Computer (stand-alone)</td>
<td>Digital alphanumerics, digital graphics, digital audio, digital video</td>
<td>Floppy/Removable disks, CD-ROMs</td>
<td>Mail system, computer classroom in local learning center</td>
</tr>
<tr>
<td>Computer network</td>
<td>Digital alphanumerics, digital graphics, digital audio, digital video</td>
<td>Course-on-demand, (COD)</td>
<td>Computer network</td>
</tr>
</tbody>
</table>

to the learners by mail or placed in computer classrooms in local learning centers. The major advantages of computer-assisted learning (CAL) are its branching and management capacities, which allow instruction to be adapted to meet individual learner’s needs and learning styles.

The use of computer-mediated networks can be considered the fourth generation of technology applied to distance education. The major difference between stand-alone computers and computer-mediated networks is the possibility of having on-line, real-time interactions among teachers, between teachers and students, and among students [4]. The printed mail and broadcasting that categorized the first two generations of distance education are basically one-way communication media. Students had few ways to communicate with other students using these technologies, and teachers needed to make special arrangements to receive feedback from students. Individual computers or CAL provide chances for students to work more interactively with learning materials, but not with teachers or peers. With the recent rapid advances in computer networking techniques, on-line and real-time interactions make it possible for even solitary learners to work cooperatively in distance education. Computer networks facilitate three basic types of interactions required in conventional classrooms and preferred in distance learning: learner-content interaction, learner-instructor interaction, and learner-learner interaction, as identified by Moore [5].

Table III shows student activities mapped from conventional classrooms to computer-networked distance learning settings. Most of the basic student activities, such as receiving lectures, taking notes, working on individual assignments, accessing grades and averages, and receiving school administration information, can be accomplished using computer-networked distance learning. Some activities requiring face-to-face interactions between teachers and students and among students, such as in- and out-of-class discussions, can be supported by communication facilities such as the electronic conference systems provided by computer networks.

Cooperative and Collaborative Distance Learning

The communication capacities and facilities of computer networks provide a learning context that may foster cooperative and collaborative learning at-a-distance. While most real-world tasks are preferably cooperative endeavors due to their complexity, severe time constraints, or the requirement for broad experience [6], cooperative learning is seldom encouraged and practiced in conventional classrooms [7], or in distance learning. Alexander [8], Steeples [9], and Watabe et al. [10] stated the benefits of collaborative learning that may be realized in distance learning settings:

1) The students benefit from different viewpoints or perspectives on the material they are learning. This can lead to refinement and deeper understanding of the materials.
2) Collaboration supports and encourages the sharing of individual expertise and experience. The group collectively brings with it a broader range of experience than does any individual member.
3) In the process of collaborative learning, students are required to present, explain, and sometimes defend their contributions to peers. By communicating what they have learned to other students, their learning will become more integrated into their general understanding, and can lead to broader application and generalization of the knowledge.
4) Collaborative learning can lead to a sense of involvement and identification with groups and their products. This supports the human need to interact with others, which is usually unsatisfied by distance learning.

However, collaborative learning cannot be guaranteed to occur effectively and efficiently simply by giving students a computer-network-supported system and telling them to get on with learning [8]. Collaborative learning will not be successful if the collaboration is not highly motivated and not
### Mapping Student Activities from Conventional Classrooms to Computer-Networked Distance Learning Environments

<table>
<thead>
<tr>
<th>Activities</th>
<th>Conventional classroom</th>
<th>Computer-networked distance learning environments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>Mostly from teachers</td>
<td>From course-on-demand (COD)</td>
</tr>
<tr>
<td>Note-taking</td>
<td>To paper notebook</td>
<td>To electronic notebook</td>
</tr>
<tr>
<td>Discussion</td>
<td>Face-to-face between teachers and students, among students</td>
<td>Computer-network conferences, sub-group computer conferences, E-mail messages</td>
</tr>
<tr>
<td>Individual assignments</td>
<td>Assignment-on-demand</td>
<td>Computer-mediated task assignment based on student profiles, teacher-set parameters, etc.</td>
</tr>
<tr>
<td>Group project</td>
<td>Face-to-face group formation, task assignment</td>
<td>Computer conferences or E-mail systems</td>
</tr>
<tr>
<td>Learning from resources</td>
<td>Books, class notes</td>
<td>Reference-on-demand, indexed library of electronic books</td>
</tr>
<tr>
<td>Evaluation and feedback</td>
<td>Practice book</td>
<td>Practice-on-demand with immediate feedback</td>
</tr>
<tr>
<td>School administration information</td>
<td>School bulletin board</td>
<td>Electronic bulletin board system (BBS)</td>
</tr>
</tbody>
</table>

An essential part of the communication transactions over the computer network. In order to promote and support collaborative learning, three major components must be integrated into any distance learning scheme: computer-network-supported communication channels, cooperative learning courseware and tasks, and cooperative learning strategies. Therefore, what is needed and preferable is an integrated and interactive distance learning system in which communication channels can be provided, courseware and tasks can be presented and managed, cooperative learning strategies can be utilized and assessed, and interactions can be facilitated and recorded for further study and analysis.

**The CORAL Case**

The Cooperative Remotely Accessible Learning (CORAL) system is a network-based computer-assisted learning system that supports cooperative distance learning in technical communication education. It is currently under development.
at National Chiao Tung University (NCTU), one of Taiwan's leading educational institutions devoted to instruction in science and technology. The CORAL project involves 10 faculty members and more than 30 graduate students. Because our science and technology students are likely to attain management levels soon after graduation, technical communication is in great demand at NCTU. The courses in technical communication will increasingly be provided via the CORAL system in the months and years ahead, not only to serve NCTU students, but also to serve scientists and engineers on the job. Besides learning materials and activities conveyed by the courseware, CORAL also provides students an integrated computer-network-based means for transporting their educational experiences, with interactive communication tools and channels, to their eventual career environments.

**The CORAL Design Approach**

Because an iterative, user-centered design-evaluation approach was adopted, learner analysis was first conducted before the development of the CORAL functions, features, courseware, and cooperative tasks. Empirical data were collected by interviewing a sample of 42 students out of a total of 1000 freshmen at NCTU. Interview results indicated that most of the students had little or no experience of cooperative learning. This was not surprising to the researchers because the major, if not the only, teaching strategy used in Taiwan classrooms before post-secondary-school education is large-group instruction. Most students study individually and competitively throughout their junior high school years in order to prepare for city- or county-wide high school entrance examinations, and then throughout their high school years for the national college entrance examination. In other words, cooperative learning is not at all part of Taiwan student life before college. College thus seems a logical starting level at which to introduce cooperative learning in Taiwan; however, since our students are required to choose their majors upon entering colleges and universities, they may have opportunities to learn cooperatively within their departments, but will rarely have such opportunities for interdisciplinary cooperative learning. While team approaches are applauded and preferred in Taiwan, our students have few chances to learn cooperative skills and to experience team dynamics, especially when more than one department is involved. This presented a great challenge to the developers of the CORAL system in introducing cooperative learning in distance situations.

Furthermore, in the Chinese tradition, students are almost completely accustomed to a top-down communication style—teacher talks, students listen—in classrooms. Thus designing a computer-assisted learning environment in which students learn mostly on their own and from peers, and recasting the teacher's role to be one of facilitating instead of lecturing, was an even greater challenge for researchers. However, planning and designing learner-controlled course-content-oriented systems for distance learners is the kind of challenge teachers and program designers should be taking on [11]. As Gunawardena [12] suggested, new paradigms are needed for development of two-way interactive technology designs. Instructional designs for cooperative distance learning systems must address the complex interrelationships among media attributes, learning tasks, and learners' cognitive processes.

**The Structure of the CORAL System**

The CORAL design comprises two major parts: a courseware browser and a group of communication channels. The courseware browser is like Netscape. By using the Hyper-Text Markup Language (HTML), authors can create hypertext nodes containing multimedia contents and use links to forward them to other nodes. A hypertext system works like a database that stores knowledge and allows users to retrieve that knowledge by navigating through hyperspace. To browse through hyperspace on the Internet, a user needs a certain type of browser. Netscape is among the most popular browsers available. It provides basic functions such as highlighted anchors, or hot keys, that represent links to other nodes, records of users' browsing histories, and loading of new nodes upon request.

However, the primary purpose of Netscape is to enable stand-alone users to navigate in the hyperspace defined by the nodes and the links to find interesting and useful information. It is not designed for instructional purposes or for collaborative learning and working purposes. Thus to achieve our goal of using hypermedia for cooperative distance education via the Internet, we needed to enhance the functions provided by the original Netscape browser.

In the CORAL system, students have three ways of navigating the learning materials. The first is to use the above-mentioned hot keys, which allow them to jump to selected nodes. The second is to use "next" buttons at the end of each node indicating the designer's recommendation for the next node to visit. Finally, a tree-like overview map of the whole course structure is provided, and students can click on the map to proceed to any part of the course they wish to go to. The second and third ways are enhanced functions not found in Netscape. Fig. 1, a sample screen from the CORAL system, shows the browser for course content. Some words in the text are colored as hot keys, and the "hand" at the bottom of the text represents the Next button. A tree-like overview map is in the left part of the screen.

The CORAL system provides students five channels over which to communicate with their teachers and peers. Provision for off-line communication includes a BBS-like notebook that allows both teachers and students to leave messages such as assignments, meeting hours, questions, and responses.

Four channels are provided for on-line communication. The first channel gives students a Chat Room that allows them to type what-you-see-is-what-I-see (WYSIWIS) text on-line, as suggested in Dede [13]. The second channel is a co-edited Electronic Whiteboard, which is similar in function to the Chat Room. Students can use this E-whiteboard to type, draw, and paint. It is especially useful for presenting graphic information such as mathematical formulas, tables, and programming flowcharts.
The third and the fourth channels are an audio window and a video window that allow students to communicate with their teachers and other students. These windows convey voice messages, and nonverbal messages, such as facial expressions. The audio/video windows provided by CORAL indeed help to create a "social presence" for the system; that is, the system permits users to experience others as if they were face-to-face.

Fig. 2 shows the communication channels (four on-line and one off-line) provided by CORAL; from top to bottom they are the notebook in the lower-left, the audio and video windows, the Electronic Whiteboard, and the Chat Room at the right.

When a student requests the talk function from the menu bar, the system shows a list of all students in the same course who are on-line at the time. Students can then form discussion groups by arranging conferences, or by breaking in on in-progress conversations. After the discussion group is formed, students can choose appropriate channels to communicate with each other on-line according to task requirements and facilities constraints.

Table IV summarizes the communication channels provided by CORAL. It is arranged to show each channel in terms of its mode of communication, the information delivered, the communication application, educational values, equivalent future work values in business and industry, and the required equipment costs. Note that the notebook, Chat Room, and E-whiteboard and the audio conference are directly implemented on the Internet. These three channels require only the regular networking facilities of a personal computer, so the cost is low. Audio conferencing requires additional microphones, speakers, and sound cards; therefore, the equipment cost is somewhat greater. By contrast, the video conference channel requires high-speed network equipment, i.e., fiber-optic links; therefore, purchase and installation costs are high.

Coral Courseware and Cooperative Task Design

Courseware entitled "An Introduction to Communication Technology" was designed for the sequence of courses on the technical communication track that will be offered in the graduate program at NCTU's Institute of Communication Studies. The course will address major issues such as computer technology, digital video, electronic magazines, teleconferencing, and satellites. For this course, a prototype "Computer Networks" unit was first created. The development of the courseware includes analysis, design, production, evaluation, and revision phases, as shown in Fig. 3.

In order to collect demographic data, prior knowledge, and information about past computer use, a questionnaire was distributed to the 42 sample target-learners. A list of 20 keywords, such as ISDN, WWW, and ISO protocols, was used to check students' entry knowledge of the subject matter. The questionnaire indicated that most of the learners had just graduated from high schools and that half of them had their
own personal computers but had little knowledge of computer networks. Some had heard of BBS's and/or the Internet.

After the learner analysis, the next steps were to state the course objectives, analyze the learning tasks, and collect the learning materials for the course content. Basic computer networks topics were addressed, including hardware, software, data-transfer techniques, protocols, applications, security, management, and maintenance. Rough-draft basic, intermediate, and advanced learning materials were organized for each area of courseware. Required multimedia components including graphics, video, text, audio, and animation were identified. A Web format page layout was designed, and storyboards for each node were created by designers to help visualize graphics, animation, and/or video clips added to the text-based content.

In the production phase of the courseware for CORAL, the multimedia presentation components, as visualized in the storyboard, were developed and then written in HTML format. A working prototype course consisting of 100 instructional nodes was created so that the system and course could be more easily evaluated and revised.

The elaboration theory of instruction [15] was adopted as the theoretical foundation for content structure. The elaboration theory prescribes that instruction starts with a special...
kind of overview that introduces a few general, simple, and fundamental ideas. The remainder of the instruction presents progressively more detailed or complex ideas that elaborate on previous ones. This is similar to the “overview node” for hypertext writing suggested by Shneiderman and Kearsley [16]. In the overview node, each subtopic is a hot key or an anchor built into the text. In the CORAL system, for example, an overview of computer network applications is presented in one node. Subtopics such as office automation, BBS’s, and Gophers are colored hot keys in the text. An overview node gives only a very brief description of a subtopic. After reading the contents of the overview node, students can use any hot key to jump to another node for more details or more advanced instructions. The contents of each instructional node, as visualized in the storyboard, were written in HTML format. Hot keys for each node were identified, and the destination nodes these hot keys are linked to were also specified.

In order to initiate and encourage cooperative learning, a group project was designed and tested by a group of three learners. The project required them to build a LAN system in a computer lab. The problem and the context were presented, and the “virtual resources,” i.e., the money and time each group could use, were given. Students were required to conduct a needs analysis and to document user requirements, then sketch a floor layout in which hubs, repeaters, and ports were specified. Literature suggests that students may not know how to work cooperatively and efficiently unless they are first given appropriate learning strategies [17]. In order to prevent a possible deficiency in this area and to enable the group to progress cooperatively and effectively, a copy of “CORAL Group Project Guidelines and Procedures” was given to each group member. The guidelines suggested students use collaborative skills including:

1) oral summarization: verbal paraphrasing of information to be learned
2) careful listening and checking for understanding
3) constructive feedback, and other such techniques.

The procedures required the group to progress in the following order:

1) Social interaction: group members got acquainted with each other.
2) Goal setting: the group had to decide the group goal, in this case, a complete floor layout of the computer lab with a budget list.
3) Task allocation: the group had to divide the task into subtasks and assign each subtask to group member(s). Usually this can be done in two ways: top-down and bottom-up. In this group-project trial, because no teacher was involved, the bottom-up approach was expected, that is, the three group members would allocate tasks on an equal basis.
4) Individual accountability: during the group processing, each group member’s task and progress were to be checked frequently.
5) Integration of the group product and assessment: the group had to verify completion of each subtask and integrate all subtasks into a presentable format.

CORAL System, Courseware, and Task Evaluation

A formative evaluation was conducted to examine the usability of the CORAL system and the instructional effectiveness of the course. Two major evaluation approaches were adopted: expert-based and user-based [18]. One experienced computer science instructor who has been teaching computer networks for years was invited to check the correctness of the course content. Therefore, a written comprehension test was conducted after each student claimed he or she had finished the course. This test consisted of three types of questions: knowledge, comprehension, and application. The test scores indicated that students did acquire basic knowledge from the course. The test results were then revised according to his evaluation results.

The same 42 sample target learners upon whom we conducted learner analysis in the courseware design phase participated in the user-based formative evaluation. Reiser and Kegelmann [19] stated that the evaluation of instructional software is incomplete without a report on student learning performance. Therefore, a written comprehension test was conducted after each student claimed he or she had finished the course. This test consisted of three types of questions: knowledge, comprehension, and application. The test scores indicated that students did acquire basic knowledge from the course. The test results will help instructional designers identify and revise ambiguous parts of the content.

An expert-based heuristic evaluation method was employed to evaluate the system usability, that is, its learnability, efficiency, memorability, error rates, and satisfaction [20]. Heuristics are usability principles that serve as a basis for systematic inspection of usability problems [21]. Nielsen and his colleagues [22], [23] derived 10 heuristics from a factor analysis of 249 usability problems identified from many research studies. The 10 heuristics are:

- Visibility of system status
- Match between system and the real world
- User control and freedom
- Consistency and standards
- Error prevention
- Recognition rather than recall
- Flexibility and efficiency of use
- Aesthetic and minimalist design
- Helping users recognize, diagnose, and recover from errors
- Help and documentation

During the heuristic evaluation, each heuristic was further defined to help usability experts grasp its underlying significance. For example, “visibility of system status” entails providing appropriate feedback to users’ inputs within reasonable times. “Match between system and the real world” suggests the system should speak the users’ language rather than using system-oriented terms. For more detailed explanations, please refer to Nielsen [20] and Chou [24].

Four usability experts were invited to conduct the evaluation. Two of the four usability experts we invited are instructional technologists with training in interface design. The other two have expertise in both computer networks and usability.

The evaluation procedure consisted of having these evaluators individually go through the system at least twice. The first time was intended to give them a feel for the flow of the interaction and the general scope of the system functions. The second time allowed the evaluators to focus on specific interface features or problems. They were required to write down the usability problems on paper and point out the number of heuristic(s) violated by each problem. The heuristic evaluation identified 33 usability problems. Some problems were quite serious and needed to be fixed immediately, or at least before user testing. For example, after the Electronic Whiteboard was closed by a learner, there was no way to open it again (violating the heuristic “User control and freedom”). Some problems were minor, but needed to be fixed before completion of the system. For example, explanations had to be provided for each icon (otherwise, “Recognition rather than recall” would be violated).

Students’ reactions to the usability design were also collected using a Likert scale as well as open-ended questionnaires. Observations and interviews of selected learners were also conducted during and after their learning experience. In general, students expressed positive attitudes toward the usability design. They thought it was interesting and helped them learn the content. More than 80% of the students agreed that the illustrations helped them understand the text. Most of the students appreciated the course’s being in Chinese, with English translation for special terms. On the other hand, some usability problems were also identified during the evaluation. For example, students thought there were too many items on the menu bar and that their functions were not intuitively obvious. Students requested that the name of the node presented in the overview map change color whenever they had previously visited that node.

A more interesting result of the formative evaluation came from the group project that required cooperative learning and problem-solving. Two kinds of evaluation data were collected: one from computer-recorded Electronic Whiteboard data, and the other from observations at the evaluation sites. Both kinds of data indicated students were first overwhelmed by the novel functions in the CORAL system. They spent some time acquainting themselves not only with other group members, but also with the functions and features of the system. After some practice, students were able to communicate with each other quite effectively and perform their group task cooperatively. Unexpectedly, students did not adopt the bottom-up approach in allocating group tasks in this teacher-less setting. Instead, a leader emerged and exerted his influence and control over the rest of the group process and members. This enabled the entire group project to progress very effectively and efficiently. This result supported Resnick’s [25] observation that students tend to adopt centralized top-down cooperative learning approach, even in a setting specifically designed for decentralized bottom-up cooperative learning. The result of this trial indicated Taiwan students can be trained to perform cooperative learning tasks given appropriate tools, tasks, and strategies. However, the designers of the CORAL system are working on developing more complete training materials to promote and help cooperative learning.
FUTURE RESEARCH AND CONCLUSION

An abundant and interesting courseware database is indispensable for the success of any CAL system. Ongoing CORAL courseware development includes units in Multimedia Information Superhighway and the World Wide Web System.

The CORAL system also provides a research environment; ongoing research projects can be conducted in four major categories: student behaviors and learning guidance, cooperative learning strategies, aptitude treatment interaction, and evaluation methods.

The most important question in designing a computer-network-assisted learning system is: what is the interrelationship between the system attributes and student behavior? Since the CORAL system is based on a hypermedia architecture, and its courseware is constructed and presented in a hypermedia format, the study of learners' behaviors, e.g., navigation through hyperspace, is fundamental and interesting. With built-in recording and tracking functions, information on students' navigation paths can be recorded and patterns can then be analyzed. Algorithms, developed based on computer graph theory, can extract similarity information from pairs of navigation paths. The same technique can be used to measure the degree of linearity of a given path, that is, the degree of linearity of paths students follow in navigating through hyperspace. Preliminary results were reported by Sun and Ching [26].

Various navigation maps using student behavior for learning guidance are under development to help students achieve their learning goals. For example, in the dimension of "locality," three types of map—global, local, and local tracking—are provided in CORAL. The global map provides an overview of the entire hyperspace, as shown in Fig. 3. A local map focuses on only the neighborhood of an activated node. The local tracking map is similar to the local map, but always shows the activated node in the center of the map in "You-Are-Here" fashion. Research studies are in progress to investigate the effects of student cognitive styles (e.g., field dependence) and the use of these maps on concept mapping, efficiency of search tasks, attitude, and so on.

Since cooperative constructive learning is one of the major purposes of the CORAL project, instructional strategies for cooperative learning are being designed and studied. For example, a strategy called "Learning by Judging" was in its pioneering experimental stage. From experimental results of our courseware study on nuance theory, we found that this learning strategy is suitable for case-based evaluative learning. It can be employed in the early stages of instruction to encourage active learning because it requires a minimum amount of prior knowledge about the subject matter. In addition, this new strategy stresses social interaction in learning activities in order to establish community consensus and to lead the learners to construct and reconstruct their knowledge. We fed back the analytical results of the learning patterns to the learning-by-judging students to help them realize their inner cognitive processes as well as the effects of social interaction.

The basic idea behind Aptitude Treatment Interaction (ATI) is that students with different aptitudes should be given different tutoring, interaction mechanisms, and courseware content. In traditional classrooms, this goal is difficult to achieve because of limited resources. By contrast, it is possible to specially tailor-made courseware contents and presentation for students in a computer-network-supported learning system like CORAL. For example, students whose cognitive style is deep-processing may prefer extra examples and explanations of the content, while students whose cognitive style is shallow-processing may benefit more from a table-of-contents-like overview map. Students whose perceptual style is more visually oriented may prefer graphic presentations, tables, and charts, while students who are more sound oriented may prefer narrations and "earcons." Results of studies on students, and interaction-style analyses under development using CORAL, will help ATI workers construct better and more usable interactive distance learning techniques.

Evaluation and testing methods are another focus of our research effort. For example, a new computer recording technique, called Computer Logging of User Commentary (CLUC) is designed for formative evaluation of interactive learning systems [27]. The CLUC method can be considered a hybrid technique that uses computer logging techniques to collect commentary during users' interactions with the learning materials presented in a computer-network-assisted distance learning system such as CORAL. CLUC is designed to collect inputs from large numbers of users working in different locations. The inputs are automatically stored, counted, and then presented in an easily interpreted format for formative evaluators and system designers. The basic idea came from the authors' experience of conducting formative evaluation of the CORAL course. Several students indicated in their open-ended questionnaires that more definitions for some terms were needed. When we interviewed them to get further details about the identity and location of the terms, they had difficulty finding those terms in a 100-node web. CLUC is being developed to allow students to immediately mark contents they think should be revised.

The CORAL system we have described is a collective and interdisciplinary project intended to integrate four major components in concept and construction: an interactive learning environment, educational foundations and implications, domain knowledge, and research efforts. Through development of the CORAL system, involved faculty and students from different disciplines experienced collaborative learning themselves, occasionally in distance situations. This experience gave us more insight into and inspiration for developing CORAL. We expect that more research will be conducted into cooperative distance learning techniques, and that more systems like CORAL will be developed to benefit students in technical communication education.

Note: Since the CORAL system's browser is compatible with Netscape, readers around the world can use Netscape to retrieve currently available courses, such as "An Introduction to Computer Networks" (in Chinese), from http://coral.cis.nctu.edu.tw.
REFERENCES


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