# AN ATTEMPT TO DESIGN SYNCHRONOUS COLLABORATIVE LEARNING ENVIRONMENTS FOR PEER DYADS ON THE WORLD WIDE WEB


**FONG-LOK LEE**
*The Chinese University of Hong Kong*

**STEVEN LIANG**
**TAK-WAI CHAN**
*National Central University, Taiwan*



### ABSTRACT

This article describes the design, implementation, and preliminary evaluation of three synchronous distributed learning prototype systems. Each of these systems supports a particular style of interaction, referred to as a socio-activity learning model, between members of student dyads (pairs). The first two systems, Co-Working System and Working Along System, are realizations of two basic models of collaborative, one-on-one, synchronous, and networked learning, while the third one, the Hybrid System, is a combined model of the two. This work intends to identify a set of domain independent tools necessary for these models and collect information for future development through some preliminary evaluation of some experimental trials of these systems. All these systems were implemented on WWW using the computer language Java.


## INTRODUCTION

Traditional classroom teaching is teacher-centered, that is, for most of the time, there can only be one-to-many communication, mainly from the teacher to the students. A classroom or lecture hall setting does not normally encourage interactions among fellow students. It is well understood that peers have a private language that is different from that used by teachers. Students are in a better position to understand the difficulties of their peers. It stands to reason then, that both the private language and the mutual understanding among students are vehicles for enhancing students' learning, making student collaboration something to be encouraged whenever possible. Normally, in a class a student has only one teacher but tens of classmates who are knowledge sources from whom the student can benefit. The intention of overcoming the limited interactions in a traditional classroom setting underlies most of the recent effort in adopting networks in education.

The advent of Internet technologies has recently spurred a lot of interest in their applications in every sector of society. Internet potentially connects all the people, content, and computing power in the world. Yet for education, if the Internet has only one important impact, then it must be the various possible means of learning interactions on the network, which will ultimately extend the ways of human learning. For instance, the computer network provides a unique opportunity for experimenting with peer-collaborated learning which may not be viable in traditional classroom settings. Though it cannot replace the normal teacher-centered learning situation, it can be a useful after-class supplement. The crux of this research is how the network can facilitate peer-collaborated learning in a feasible and productive manner.

This work is part of the on-going research project called LISA. The project focuses on socio-activity learning system research, in particular the study of the system's structure, protocol, implementation, and performance. Structure is the constitution of the learning environment and those are involved in it. Protocol is a set of rules that governs the learning activity. Structure and protocol together define a particular socio-activity learning model. Implementation is the realization of the model with a particular technology. That realization is an instance of the socio-activity learning model. Performance is about the learning effects and usage of the systems.

Structure deals with the physical configuration and the number, types, and composition of the agents involved in the environment. Configuration is either centralized, that is, having a group of students sitting in front of and using a single computer, or distributed, that is, having multiple students working together across connected machines. Agents can be real or virtual. Real agents are the human users, including students, teachers, or teaching assistants. Virtual agents refer to simulated educational agents such as virtual tutors, learning companions, assistants, or any artificial roles in an educational role playing games. Note that in the future virtual educational agents will be able to migrate from one computer to another computer in the network.

Socio-activity learning protocols can be roughly categorized as collaborative, competitive, peer tutored, role playing games such as those in MUD (Multi-User Dungeon, Dimension, or Domain) games and so on. Every category consists of various protocols. For example, in collaboration students can co-work on the same task at the same time or they can first divide the task into sub-tasks, carry out one sub-task each, and then combine the results of their sub-tasks to accomplish the final task. A protocol can also be synchronous or asynchronous, that is, whether users interact at the same or at different times, for example by using electronic



mail or exchange directly such as chatting (text or voice) on the Internet. For competition games, students can compete against each other at the same time or students can try to perform better asynchronously so as to defeat those with higher scores on the score board.

Implementation largely depends on the availability of technology employed at the time of the system development. For example, in 1990 we used an RS232 PC network to connect two PC386 in the laboratory and had dyads play a competition game. Later we switched to two PowerMacs to design a multimedia interface for the system. We also use C++ to write a server system to see whether the dyad competition game can be played on the Internet. In the past, we had to find subjects to test our system in the laboratory, but now we simply tell the students the address of the system which they can then test at a place of their convenience. We have experienced the effect of technology changes in our work. While new technology quickly made our prototype systems obsolete, it gave rise to opportunities for new avenues of research. As will be seen in this study, technology also determines how powerful the set of tools will be, which are used to support a socio-activity learning model.

## Cognition, Motivation and Sociability

Cognition, motivation, and sociability are some aspects of the performance of socio-activity learning systems. Social cognition stems from several views, but all of them stress that social interactions play a fundamental role in individual cognitive development. Some consider that knowledge is distributed among individuals and learning is viewed as an inter-mental process [1]. Knowledge internalization occurs when an interpersonal process at the social level is transformed into an intrapersonal process at the individual level. Another perspective is the participation in a community of practice [2], in a knowledge-building community [3], or in a community of learners [4]. From this perspective, learning is viewed as a process in which learners construct knowledge and negotiate meanings together. Indeed, if we view knowledge as a common consensus of our community, then learning can be regarded as the process of knowledge co-construction, synchronously or asynchronously, through various media and means. Socio-activity learning system research, from the cognition perspective, aims to design networked learning environments that can provide an appropriate social context to serve as a catalyst for knowledge cultivation. For example, a student can look at situations from the multiple perspectives raised by fellow students, plan, evaluate new ideas, monitor, and assess solutions while keeping an eye out for possible mistakes made by others.

## Motivation

While cognition concerns whether the student *can* learn, motivation concerns whether students *will* learn. As Clancey put it (quoted in [5]), cognition and motivation are not separable in learning. There is no human cognition without value, interest, and attention; they are part of cognition already. However, learning is energy consuming, and motivation will not be there if we do not nurture it. In a socio-activity learning environment, to keep students motivated is to keep students wanting to participate: providing an opportunity for the student to contribute something, to be stimulated or provoked in some way, to be a little bit off balance, and to bring the previous understanding together. The challenges may be raised by peers, with some help from the teachers

## Social-Cognitive Conflict

What accounts for the improved cognitive development through interaction with a peer? Doise and his colleagues [6] suggested that such improvement is caused by *sociol-cognitive conflict.* In the pair situation, the child finds himself or herself confronted with alternative and conflicting solutions which, while not necessarily offering the correct response, may suggest to him "some relevant dimensions for a progressive elaboration of a mechanism new to him" [7]. Therefore, it is the active resolution of the cognitive conflict on the learner's part that accounts for the improved learning under the influence of social interaction.

Experiments by Doise and his colleagues [6] have shown that two children working together can successfully perform a task which cannot be performed by children of the same age working alone. Their subsequent experiment [8] further indicates that "more progress takes place when children with different cognitive strategies work together than when children with the same strategies do so, and that not only the less advanced but also the more advanced child make progress when they interact with each other." More recent work by Petitto [9] also illustrated that the approach taken by a pair of students to an estimation task can often be qualitatively different from the approach taken by either student alone. Once the new approach emerges, it then becomes part of their repertoire.

Doise and his colleagues do not further illustrate what constitutes a cognitive conflict. In a broad sense, we can view it as some idea or point of view that arises whenever one agent's response does not completely match the other agent's knowledge. Unlike a teacher's response, which intends to focus the student back to the supposed correct path, cognitive conflict represents a conflictual dilemma that needs to be reconciled by both agents. Cognitive conflict is not a rare phenomenon. It occurs very often, for two agents' knowledge seldom overlaps completely. When cognitive conflict occurs, the learners are forced to examine their thinking, and to look for alternative perspectives hinted at by the conflict and at the same time keep an eye out for possible relevancies. Both agents need to diagnose and evaluate problems indicated by the cognitive conflict and to justify their own perspectives.



## Computer-Mediated Communication

Peer cooperation is seen in a Vygotskian way as an intermediate stage in the developmental process of internalization of social activities [10]. Current technology not only enables efficient communication (e.g., [11]), it also enables efficient cooperation or collaboration over distance. However, efficient communication cannot also be guaranteed to be effective. Regarding collaborative learning, an effective communication may be best described as a social process of participating in a community of practice by means of collaborative sense-making, in which knowledge is used as a tool to solve emergent problems [2].

The usual practice in investigating the effectiveness of computer-mediated communication is to compare it to face-to-face interaction. Since body language and facial expressions cannot be conveyed through this kind of communication, it is thought that there could be little support of the exchange of socio-emotional information, resulting in a negative social climate [12]. Computer-mediated interaction, then, seems to occur in a social vacuum [13], when compared with face-to-face communication. To the contrary, a study by Riel and Levin suggested that the lack of social cues could be compensated by other means [14]. In a distance learning course on computer-mediated communication and education, Lai [12] found that social relationships between the students could be developed using the Web by the exchange of socio-emotional information in ways of: salutation, thanking, personal reference, acknowledging and praising other participants' contributions and participation, and sharing personal information. Therefore, if we wish to demonstrate that computer-mediated communication is comparable with face-to-face communication, we would have to look for signs of socio-emotional interaction by analyzing students' dialogue.

Regarding the collaboration process, some research has tried to identify domain-free components in students' dialogue. For example, a system called KIE [15] tried to help students to link, connect, distinguish, compare, and analyze their repertoire of ideas. Boxtel, Linden, and Kanselaar [16] categorized students' verbal interactions into four main functions: informative, evaluative, responsive, and directive.

More comprehensive analyses tried to link up different aspects of an interactive process. For example, Henri [17], in studying collaborative learning through computer conferencing, suggested a framework consisting of five dimensions, namely: participative, social, interactive, cognitive, and metacognitive. Oliver, Omari, and Herrington [18] used a framework consisting of four types of interaction: social, procedural, expository, and cognitive. Self [19] suggested an architecture, called DORMORBILE (DOmain, Reasoning, MOnitoring and Reflection Basis for Intelligent Learning Environments) to distinguish the four levels of agent knowledge for student modelling purposes. Cook further suggested refining the architecture into two levels [20]: "the domain and reasoning levels are the object level and equate to cognition. The monitoring and reflection levels are the meta-level."

The purpose of these kinds of content analyses, as maintained by Oliver et al. [18], was "to determine the capacity of the chosen interventions to promote dialogue and discourse through collaborative learning." It is argued however, that for students to learn collaboratively, particularly in the domain of writing Java programs, a certain amount of interchange of domain knowledge is necessary. As Hmelo, Guzdial, and Turns maintained [21], one prerequisite for effective collaborative learning is to engage the students in collaborative discussions that are focused on domain-relevant issues. Without the actual passing of knowledge from one to the other, the communication can have no educational value.

The above discussion leads to the development of a tool, called the Interaction Analysis Table, for the analyses of the collaboration processes. Details of the table can be found in later sections.

### Collaborative Learning Models

In order to investigate how networked learning environments should be designed so that they can provide an appropriate social context to serve as a catalyst of knowledge cultivation, three collaborative learning models were hypothesized and corresponding systems developed. The following sections describe what the models are and the structures of systems that enable these models. The systems were tested on a small group (60 students) of university students and the results of the analyses of collected data are reported.

## THREE PEER COLLABORATIVE LEARNING MODELS

Peer group learning can be in large groups or in small groups. Large group learning such as project-based, inquiry-based learning, usually adopts asynchronous discussion forums. This study focuses on small group learning, dyads in particular, since this is the simplest and most fundamental. The students' learning task was to write Java programs, a task that would normally require more than an hour's work from each student. Moreover, these peer learning models are synchronous, that is, interactions during the writing of these programs are performed in real time. This is what makes these distinct from many project-based learning situations in which asynchronous discussion forums are adopted as a means for collaboration and the learning tasks are usually so complex that a project may take several months to finish.

While different forms of social interactions can be supported by the Internet, the present study focuses on one-to-one interactions. Three different peer learning models all allowing one-to-one interactions, were identified. In addition, three distributed learning systems, each of which corresponds to one of the peer learning models, were developed. The following sections briefly describe what



these learning models are and how the distributed learning system can be implemented.

### Co-Working Model

Figure 1 shows the structure of the Co-working Model, in which a pair of learners is required to complete tasks given by the computer. This enables the learners to build up their knowledge through communication and collaboration with their partners.

The co-working environment was a common white board (the co-working area) on which students work. This environment forces the learners to find means to share their workload, to collaborate with the partner and to coordinate the whole task, often generating a great deal of discussion and sharing of ideas. It can be seen that communication is an important element of the Co-working Model.

### Working Along Model

The structure of the Working Along Model (Figure 2) is based on the idea that learners are made to feel that they are not alone during the learning process, that there is always a peer working at the other end of the network from whom they could seek advice when they encounter difficulties. This friend would even be willing to chat with them. Again, it is hoped that the communication between the

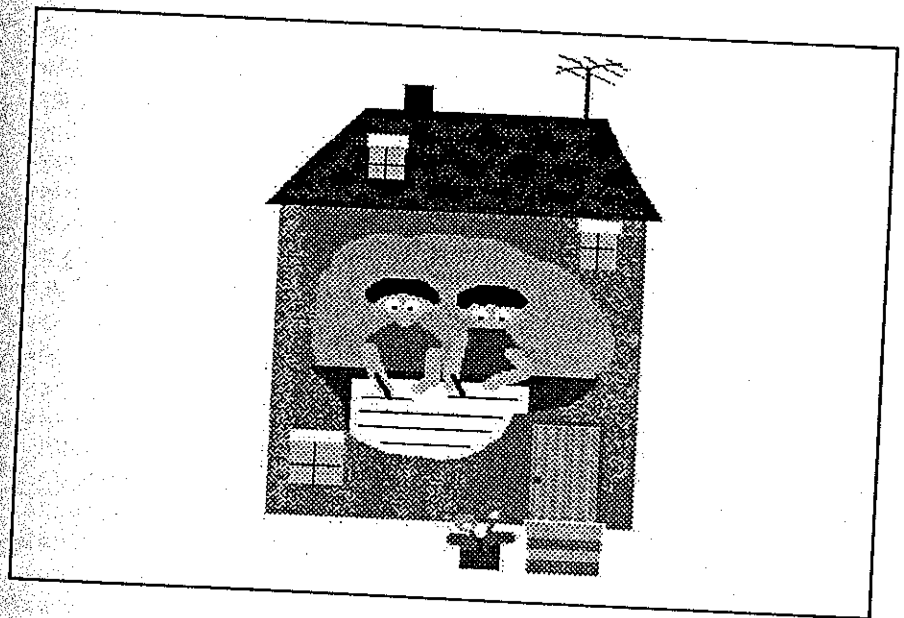

**Figure 1.** Co-working Model.

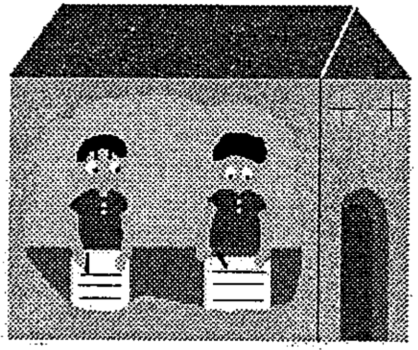

**Figure 2.** Working Along Model.

peers would help both to widen their scope of probing so as to produce better learning effects.

In this Model, two students are required to solve a problem independently, with the exception that either one of the dyad can initiate discussion whenever there is a need to do so. When one party initiates a discussion, this step serves two purposes: one party can help the other to solve the problem, but if neither can solve the problem, they are both experiencing the same difficulty and they can share each other's frustration. This would be the beginning of a process of discussion, mutual support, and sharing of knowledge which is beneficial to both as together they work out the problem-solving strategies.

"Working Along" is a common practice among students. When two or more classmates do homework together, they initially work independently but when they come across a problem, they naturally discuss it together. The advent of the computer network is simply the extension of this kind of working relationship to a much larger physical distance. This relationship is beneficial to students both in arousing their motivation to learn and in achieving better learning results.

### Hybrid Model

The structure of the Hybrid Model is as shown in Figure 3. This Model is actually a combination of the Co-Working and the Working Along Models. As in the Co-Working Model, the dyad is required to complete a given task together on a common white board, which is a co-working area. The dyad is allowed to choose their working style; they could either work on part of the problem on their own and then pool their efforts to arrive at the answer, or they could take it in turn to work in the co-working area. The Co-Working Model does not allow either of these



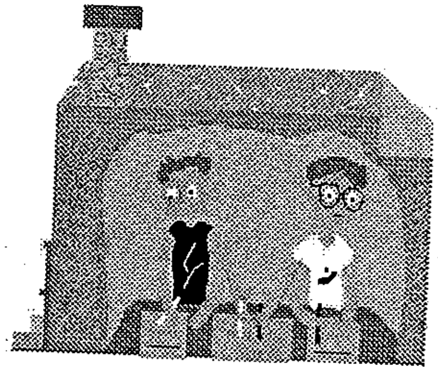

**Figure 3.** Collaborating in hybrid form.

steps; rather, all work written in the co-working area must have the consensus of both parties. The Hybrid Model is, thus, not such a strict form of collaborative learning.

## SYSTEM DESIGN AND IMPLEMENTATION

The applied domain, that is, the subject domain in which the problems are to be solved, is Java programming. The three systems that enable the above three learning models are also implemented by using Java. Since the language has networking and cross-platform features, the implementation of the system is made easier. For the system architecture, the client/server model is employed for all the three systems. The detailed structure of these systems can be found in Figure 4.

The design of the collaborative system also takes advantage of the fact that all the three learning models are collaborative learning systems which can share the same kernel to handle the collaborative learning tasks. It is only the parts of a collaborative system that are distinctive from the others which have to be implemented individually (Figure 5). The use of the kernel is important since the implementation of future collaborative systems can also be made simpler by including the kernel as a component.

### Client

The client of each system serves as the interface between the system and the users and is implemented as Java Applet. A learner only needs a WWW browser to link to our homepage to use the learning systems. All four learning systems share the same kernel part, which includes the following components:

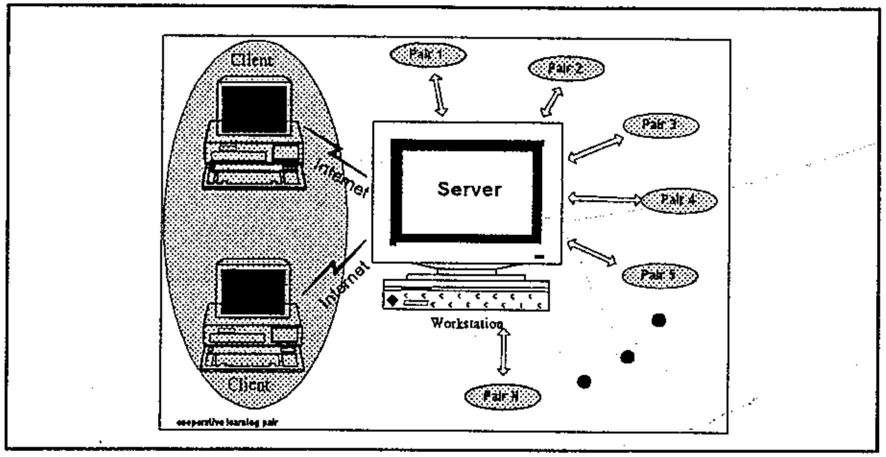


**Figure 4.** Client/Server architecture figure of systems.

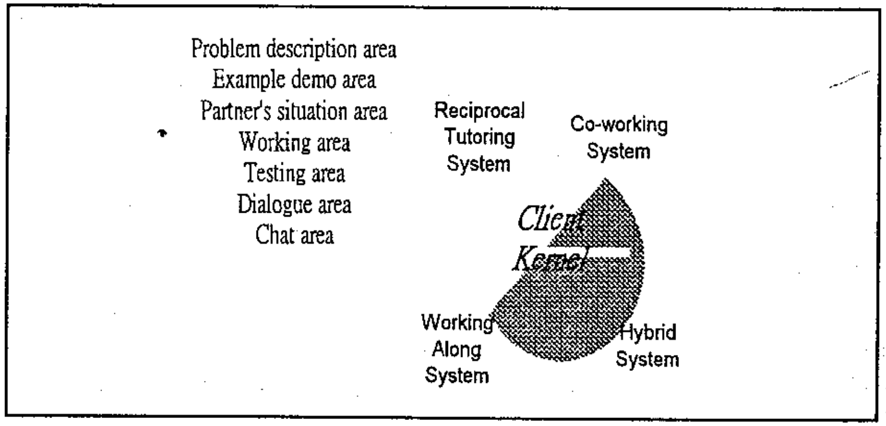


**Figure 5.** Client systems construction.

- Problem description area—where the target of the given problem is presented.
- Example demo area—where examples related to the given problem are demonstrated, showing how the target can be reached, and other related techniques.
- Partner's situation area—where learners can observe their partner's working situation.



- Working area—where learners can do their work.
- Testing area—where learners cant test their code (solution to the given problem) by having the system evaluate it. (In programming applications, this means compiling the code) Results of the evaluation are immediately sent back to the learners.
- Dialogue area—where learners can communicate with their partners using preset dialogue templates which allow easy and fast interactions without the need for typing long sentences. Different sets of dialogue templates are available in different learning systems. In addition, each template can be modified and new templates, if required, can be added.
- Chat area—where, unlike the Dialogue area, topics not related to the problems may be discussed. Members of the dyad can interact freely by typing into this area and the language used is not restricted to the dialogue templates.

With this kernel in hand, the four learning systems can be easily constructed as follows.

## Co-Working System

The interface of Co-Working System is as shown in Figure 6. A major component of this interface is the co-working area (top half of the screen) where both

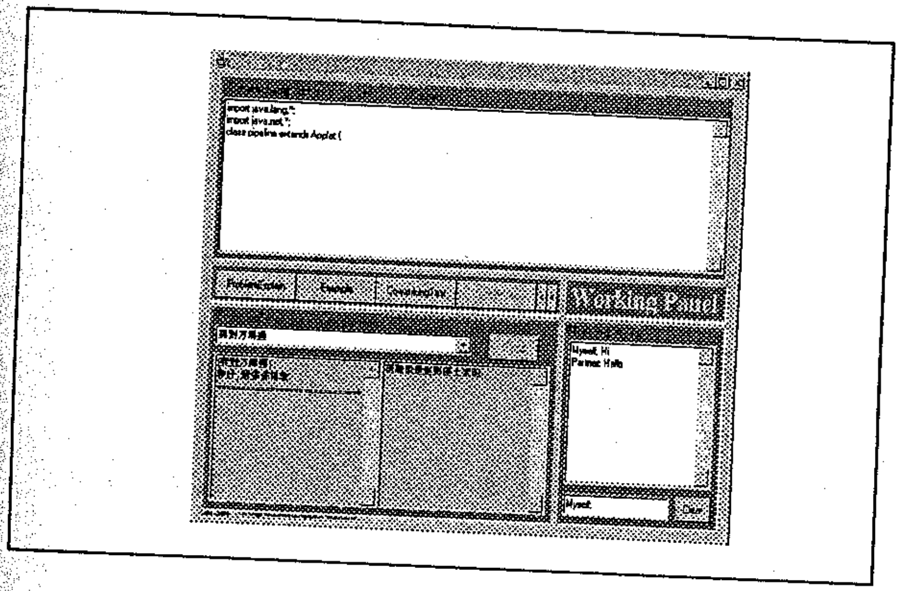


**Figure 6.** Client interface of Co-working System.

members work. Anything that is entered by one member is immediately transmitted and displayed at the other end of the network. There is no self-testing area but the learners can communicate with the dialogue (left lower half) and the chat areas (right lower half). The learners can also choose to switch off the problem description, example demo, and on-line information areas by pressing a button at the center of the screen.

## Working Along System

Figure 7 shows the screen display of the Working Along System with the learner's self-working area (top left corner) and the partner's working area (top right). The partner's work is not always updated. It is only when a learner finds such a need (for example, he or she may like to look at the partner's work as a reference) that the updating process can be activated. Whenever this updating process is activated, the partner at the other end of the network would also be informed. The system is so designed to enable learners to work without being observed.

As all other components of this system are identical to that of the Co-Working System, the discussions of these components are omitted.

## Hybrid System

The screen design of the interface of the Hybrid System is as shown in Figure 8. This system is the combination of the Co-Working and Working Along Systems.

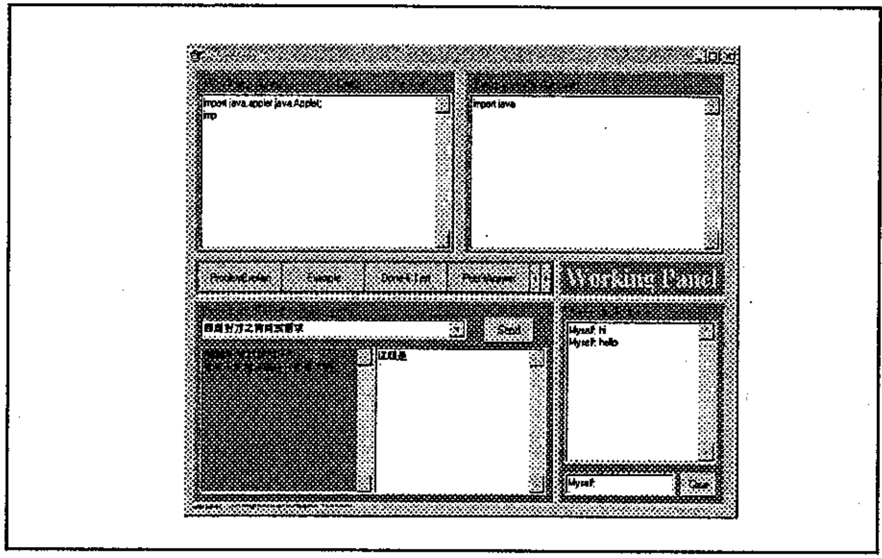


**Figure 7.** Client interface of Working Along System.



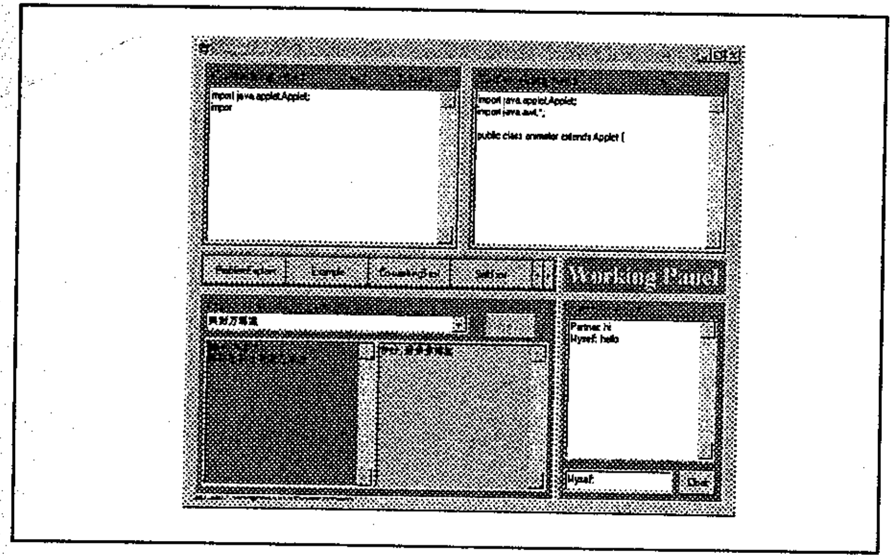


**Figure 8.** Client interface of Hybrid System.

Besides the co-working area, there is also a self-testing area where an individual learner can test his or her own ideas. The word "Hybrid" reflects this mixture of the two systems. Discussions of other components will not be repeated.

## Server

Besides the three learning systems, there is a need for a general purpose server to handle matters not directly related to learning (see Figure 9). The main functions of the server are as follows:

- Identifying learners: A learner enters his or her personal data, name, password, etc., for identification so that his or her progress may be recorded for analysis or for providing individualized feedback.
- Pairing up of learners: The system provides online user information so that the learners can choose their partners for collaborative learning.
- Presenting problems, examples, and related hints: At appropriate times, the server presents problems, examples and related hints. There is a purpose to the grouping of problems, examples and hints of the same subject into modules. This kind of domain independence means that the system can be easily applied to other domains by simply switching to another domain module.

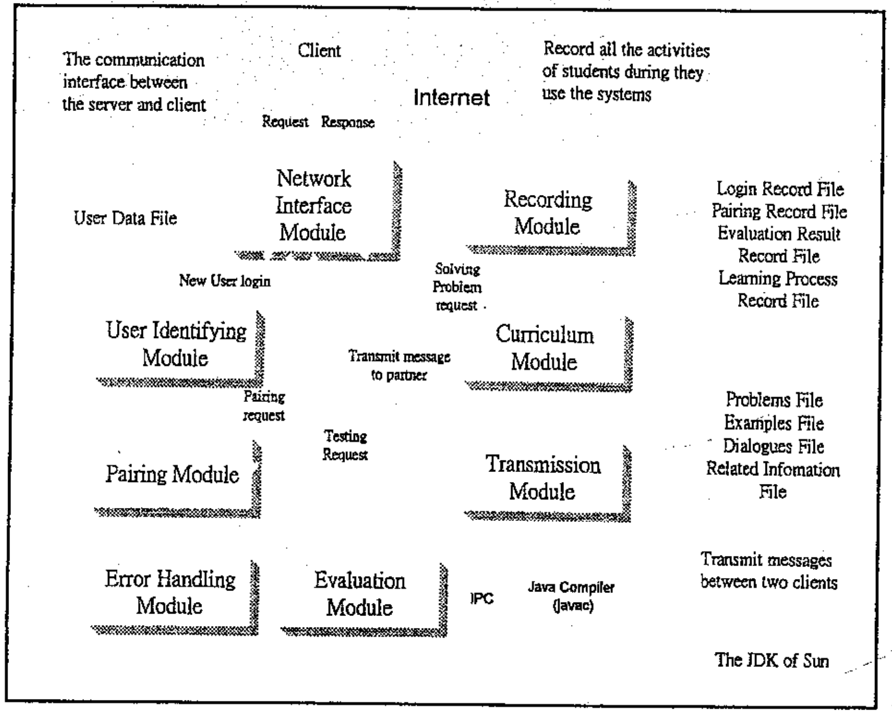


**Figure 9.** Architecture of Server.

- Evaluating learners' answer: Learners can send their code to the server for testing. After evaluating the material, the server will provide immediate feedback.
- Acting as the communicating channel between learners: Due to the limitation of Java Applet on WWW browsers, data communication between two clients needs to be transmitted by the server.
- Recording all the process of learners' collaborative activities: The learners' interactive collaborative learning process (i.e., the time to press certain buttons and input certain words, etc.) are recorded by the server for late analysis, the results of which serve to provide information for the improvement of the system.

## PRELIMINARY EVALUATION

Computer application does not necessarily have the crucial meaning of a successful learning process [22]. The success of the systems greatly depends on



whether the users learn by using the styles supported by the models. Teasley and Roschelle [23] found that "collaboration does not just happen because individuals are co-present." "If our aim is for individuals to learn then we have to examine what they take away from the exercise as well as the group's shared constructions created during the exercise" [24].

To optimize the benefits of cooperative learning, attention must be focused on the design of cooperative learning materials and activities [25]. Since positive learning outcomes from cooperative learning are contingent upon effective student interaction, which is influenced by factors such as task structure, rewards, group dynamics, and interpersonal skills [26], it is therefore necessary to show that collaboration between students did occur when using the systems. A rather in-depth analysis of the subjects' problem solving process is thus required. Furthermore, if we would like to know whether the system is well-accepted by students, surveying the students' attitudes by giving them questionnaires would be the most convenient way. The systems therefore undergo a preliminary test among students before a formal evaluation of the system can be done. The following paragraphs report on the evaluation procedures and the results of analyses.

### Subjects and Procedures

A total of sixty students from two universities in Taiwan participated in the test. Of these, forty-six were from the Chung-Yuan University and fourteen were from the National Yunlin University of Science and Technology. All the participants were, at the time of the test, taking an elective course called Object-Oriented Programming (using Java), and they were required to use the collaborative systems as their homework. After finishing the homework, they were also required to complete a questionnaire designed to collect their opinion on the use of the systems.

The test took approximately one week to complete. Subjects were allowed to log into the system and pair with anyone concurrently on the network. The pair was then allowed to choose the problems (writing Java code) they would like to solve. Since students were allowed to choose any system to use, the number of students participating in each system was thus different. Table 1 shows the number of students who participated in each of the systems. Note that each student was allowed to test more than one system.

### Interaction Analyses

The success of the systems greatly depends on whether the users learn by using the styles supported by the models. Since all the systems are designed to enable collaboration through the World Wide Web, evidence is thus required to show that subjects did collaborate through the Internet and that this collaboration did benefit the students. Such evidence is required since, although the systems are designed to allow collaboration, there is no guarantee that students would collaborate with one

**Table 1.** Number of Participants in Each of the Collaborative Systems

| System | No. of Students |
|---|---|
| Co-working System | 33 |
| Working Along System | 23 |
| Hybrid System | 35 |

other when they use the system. After all, the Internet environment is different from face-to-face communication.

There is no intention in this study to show that peer collaboration through the Internet is better than with the traditional methods, neither are we going to compare the effects of learning by the three systems. In fact, to make comparisons, either between collaboration through the Internet and traditional methods or among the three collaboration models, would take much longer time. The preliminary test of the systems thus focused on whether the systems were used as designed. If evidence can be found that students did communicate with their peers to help each other to solve the problem and that there was transmission of knowledge, we can then say that the systems can in some way provide a viable way of learning. Whether this kind of learning is better than others will be a future research topic.

Testing of the systems was thus aimed at finding out whether there are some students who can use the systems to learn. This was done by analyzing the student pairs' interaction processes. A self-developed tool, called an Interaction Analysis Table, was designed to reflect this kind of interaction. It is anticipated that the inter-flow of domain knowledge is essential in order for a collaboration process to be successful, although other types of knowledge are also helpful. To further investigate the effect of using these systems and to know how well the systems were accepted, questionnaires were used to collect students' attitudes toward using the systems. Evaluation of the systems by using the Interaction Analysis Table and the questionnaires is reported below.

### *Interaction Analysis Table*

The interaction analysis table is a table with the following dimensions: categories of information, types of interaction, and ways of handling information. Each dimension is described below.

*Category of information*—A basic purpose of interaction is to communicate information, but different kinds of information communicated have different purposes. For example, a student may want to convey a piece of domain-specific



knowledge that is needed in order for his or her peer to complete the solution. In this case, the information communicated is domain-specific knowledge. On the other hand, a student might want some guidance to overcome an impasse. In this case, an instruction that tells the student to try an alternate path is a piece of knowledge related to general problem solving strategies. Finally, gratitude expressed of a completed step shows affective support. Information conveyed during an interaction is thus grouped into three categories.

The grouping of information into three categories has its purpose. Although the last two categories are important in a problem-solving process, the communication of domain-specific knowledge is essential since it is what most novices lack. Without the necessary domain-specific knowledge, one cannot solve the problem given even if one has some very useful strategies or is supported by the partner. When the students are working within a domain (e.g., Java language) which is different from the language they commonly use and in the Internet environment which may not be as effective as their common communication modes, it is particularly important to know whether this new mode of communication does enable effective communication leading a novice to successful completion of a task with the help of his or her peer. Grouping the information into three categories helps us to find the proportion of utterances that are of domain-specific knowledge during the problem-solving process.

*Type and usage*—An utterance can be of different types according to its purpose. It may be a suggestion of what should be done next, a question on why it is done so, or an instruction on the actions which should be done. There can be different ways of handling each type of utterances. An instruction can be given or followed, whereas a question can be asked or answered. Hence students' utterances can be classified into three dimensions: the category, the type, and the usage. Table 2 shows this classification. To make it easier for the reader to understand how an utterance is classified, an example taken from our study is given for each of the cells. Note that some of the cells are empty since no such examples can be found in the students' dialogues.

By using the Interaction Analysis Table, four recorded Protocols were analyzed, one for Co-Working system, one for Working Along system, and two for Hybrid System. Selection of the protocols was based on two criteria: that the problem was solved by the student dyad and that the students were trying seriously, as judged by the researcher. While what the protocols reveal may not be a general picture of how the systems were used, they do show that at least some students could use the systems in the ways designed. More effort would be needed to identify what makes a student pair work seriously, but this could be a subject for future research.

Results of analyzing student dyads in each of the three systems can be found in Appendices A, B, and C. Summaries of the analyses are reported in the following subsection.

**Table 2.** Interaction Analysis Table

| Type | Usage | Categories | | |
|---|---|---|---|---|
| | | Domain-specific | General | Emotional |
| Suggestions | Give suggestion | I think there should be a "new Thread" at the 12th line, What do you think? | We can then go on with the Test | Let us compile the codes and see what would happen |
| | Accept suggestion | OK, I will do that | Yes, let's do it | OK. Thank you for the support |
| Questions | Ask question | Why? Could you give an example? | What is your progress now? | Are you ready? |
| | Answer question | Because we want to clear the screen . . . and repaint ( ) will do update ( ) first; and update can clean the screen . . . | Oh well, I just have 2 errors | Good! |
| Instructions | Request instruction | What should I do next? | Should I start? | |
| | Give instruction | . . . and next line must start the 'Thread.' | Go on. | |
| | Demonstrate | | | |
| | Follow instruction | You are right. | OK. | |
| Strategies | Identify problem | So our problem is to . . . | We need to find a way to overcome this. | |
| | Check other's knowledge | Do you know anything about repaint ( )? | | |
| | Ellicit inquiry | Do you think this is correct? | Any idea? | |
| | Admit failure | I have no idea how to repaint. | I am sorry I still cannot do that. | |
| | Self-correction | I suppose I have done something wrong here. Oh yes, this should be . . . | | |
| Comments | Comment | Yes. This is correct. | Yes, this seems to be the correct way to do it. | I think this is great. |
| | Respond to comment | Yes. | Yes. | Thanks. |
| Others | Show gratitude | | | Oh thank God, we've succeeded! |
| | Show support | | | Never mind the mistakes, just do it. |



*Protocol Analyses*

The purposes of analyzing the protocols is to find evidence showing that the students did interact in the ways for which each of the three systems are designed. Since different systems were designed to support different collaboration styles, protocols for different systems are reported separately as follows:

*Co-working system*—The characteristic of this system is that members of a dyad work together on a common area, so whether the common area is efficiently used would be a crucial factor of the success of the system. Appendix A shows the analysis of a protocol worked under this system. Table 3 shows a summary of the types of responses recorded.

From Table 3, it can be seen that there are relatively fewer domain-specific utterances than general ones. It seems that interaction between members of the student dyad was mainly on general working strategies. Although the co-working system is designed so that two members can collaboratively work on the common working area keeping communication of domain-specific knowledge to a

**Table 3.** Summary of a Dyad's Responses During a Co-working Process

| Type | Usage | Categories | | |
|---|---|---|---|---|
| | | Domain-specific | General | Emotional |
| Suggestions | Give suggestion | | 2 | |
| | Accept suggestion | | 2 | |
| Questions | Ask question | | 4 | |
| | Answer question | 2 | 4 | |
| Instructions | Request instruction | | | |
| | Give instruction | | | |
| | Demonstrate | 1 | | |
| | Follow instruction | | | |
| Strategies | Identify problem | 1 | | |
| | Check other's knowledge | | | |
| | Ellicit inquiry | | | |
| | Admit failure | 1 | | |
| | Self-correction | | | |
| Comments | Comment | | | |
| | Respond to comment | | | |
| Others | Show gratitude | | | |
| | Show support | | | 1 |
| Total | | 5 | 12 | 1 |

minimum, this still needs further investigation since it is doubtful that this is the case. If we look further at the protocol shown in Appendix A, we can find that the problem was mainly solved by one member of the dyad and that the other member did not seem to be involved. There does not seem to be any sign of collaboration toward the solution of the problem. This example shows a weakness of the system that has to be solved in the future.

We have tried to locate a more successful case in which the solution was done by collaboration between both members of the dyad but we failed. A possible reason for this is that students prefer to pair with a stronger student so that the whole work can be done by the latter. Suitable measures to avoid this should be taken in the future.

*Working along system*—A dyad working in a working along system is characterized by members working separately but occasionally making suggestions to each other. Evidence is therefore needed to show that they really are working in this way. An example was taken from the protocols and was analyzed as shown in Appendix B. Table 4 also shows the summary of the responses.

**Table 4.** Summary of a Dyad's Responses During a Working Along Process

| | | Categories | | |
|---|---|---|---|---|
| Type | Usage | Domain-specific | General | Emotional |
| Suggestions | Give suggestion | 12 | 2 | |
| | Accept suggestion | 1 | 3 | |
| Questions | Ask question | 2 | 3 | |
| | Answer question | | | |
| Instructions | Request instruction | 1 | | |
| | Give instruction | 3 | | |
| | Demonstrate | | | |
| | Follow instruction | 3 | | |
| Strategies | Identify problem | | | |
| | Check other's knowledge | | | |
| | Ellicit inquiry | | | |
| | Admit failure | | | |
| | Self-correction | | | |
| Comments | Comment | | | |
| | Respond to comment | | | |
| Others | Show gratitude | | | 4 |
| | Show support | | | |
| Total | | 21 | 8 | 4 |



As can be seen from Table 4, members of the dyad mainly interact through domain-specific suggestions. They were collaborating in a way different from those in the co-working system. Unlike in the co-working system where one member would dominate the problem-solving process by taking up the whole problem solving task, members in this system had equal status, each commented on the other's work and suggested how to correct the errors. If collaboration is a major source of motivation, this system would give rise to better results than the previous system.

*Hybrid system*—A hybrid system is a combination of the working-along and co-working systems. Students can either work in their own stations or work in the co-working area. Hence the success of this system depends on whether evidence can be found that students did utilize both the co-working area and their own working area and that the interaction was useful. Two protocols, as in Appendices C and D, were analyzed and the summaries are shown in Table 5. As can be seen from Table 5, there are quite a lot of domain-specific interactions between members of each dyad. Further, from the protocol shown in Appendix C, members of

**Table 5.** Summary of a Dyad's Responses During a Hybrid Process (a)

| | | Categories | | |
|---|---|---|---|---|
| Type | Usage | Domain-specific | General | Emotional |
| Suggestions | Give suggestion | 3 | 3 | |
| | Accept suggestion | 1 | | |
| Questions | Ask question | 4 | | |
| | Answer question | | | |
| Instructions | Request instruction | | | |
| | Give instruction | | | |
| | Demonstrate | | | |
| | Follow instruction | | | |
| Strategies | Identify problem | | | |
| | Check other's knowledge | | | |
| | Ellicit inquiry | | | |
| | Admit failure | | | |
| | Self-correction | | | |
| Comments | Comment | | | |
| | Respond to comment | | | |
| Others | Show gratitude | | | |
| | Show support | | | 2 |
| Total | | 8 | 3 | 2 |

the dyad did use their own working area in addition to the co-working area. From the protocol shown in Table 6, we can see that members used the co-working area to communicate their views on the program. Although the problems were not solved in both cases, we can still see that the system was used effectively in helping the students

The above protocol analyses show that, in general, students using the systems were learning in expected ways, with the exception that we cannot find an example of students working collaboratively in the co-working system. However, this can be supplemented by the hybrid system, in which an example can be found where students were using the system to communicate their knowledge about the solution of the problem. We cannot say however that the systems are helpful to the students, even when these systems were used as designed. On the other hand, the effect due to collaboration as motivation to learning should not be measured on a short-term basis. It is thus not reasonable to design a short-term experiment to evaluate the effect of the systems. The above data, in a way, shows that the systems are viable means for further research. Data collected through

**Table 6.** Summary of a Dyad's Responses During a Hybrid Process (b)

| | | Categories | | |
|---|---|---|---|---|
| Type | Usage | Domain-specific | General | Emotional |
| Suggestions | Give suggestion | 3 | 2 | |
| | Accept suggestion | 3 | 2 | |
| Questions | Ask question | 4 | 2 | |
| | Answer question | 3 | 2 | |
| Instructions | Request instruction | | | |
| | Give instruction | | 1 | |
| | Demonstrate | | | |
| | Follow instruction | | | |
| Strategies | Identify problem | | | |
| | Check other's knowledge | | | |
| | Ellicit inquiry | | | |
| | Admit failure | | | |
| | Self-correction | | | |
| Comments | Comment | | | |
| | Respond to comment | | | |
| Others | Show gratitude | | | |
| | Show support | | | |
| Total | | 13 | 9 | 0 |



questionnaires, as shown in the next section, serves to provide a general picture on how the systems were used.

## Students' Perception and Achievement

This part of the study tried to collect students' feelings about all the systems as a measure of the effectiveness of the systems. In addition, the number of students who could finish the problems were also recorded by using the systems.

Participation in the experiment was on a voluntary basis. Students who joined the experiment were awarded 1 to 5 marks out of a total of 100. Such a low incentive could not motivate all the students to participate in using all three systems. It was found that some students used all the systems while some others used just one. The three systems were thus not tested by the same population; hence, results reported in later sections can only give us some ideas about students' attitude to the systems and cannot be treated as a rigorous comparison.

(a) *Do the students like the system?* As well as ascertaining whether the students would use the system as designed, we need to know whether the students like to use the system. Otherwise, the aim of motivating students by collaboration cannot be achieved. Figure 10 shows the questionnaire result.

As can be seen in Figure 10, only a small proportion of the students dislike the three systems. Since we know that the systems were operated under normal school settings, there is no need for the students to interact with others through the use of these systems since the use of the telephone or even personal contact is more convenient. In addition, if the students were not good at typing, which is essential

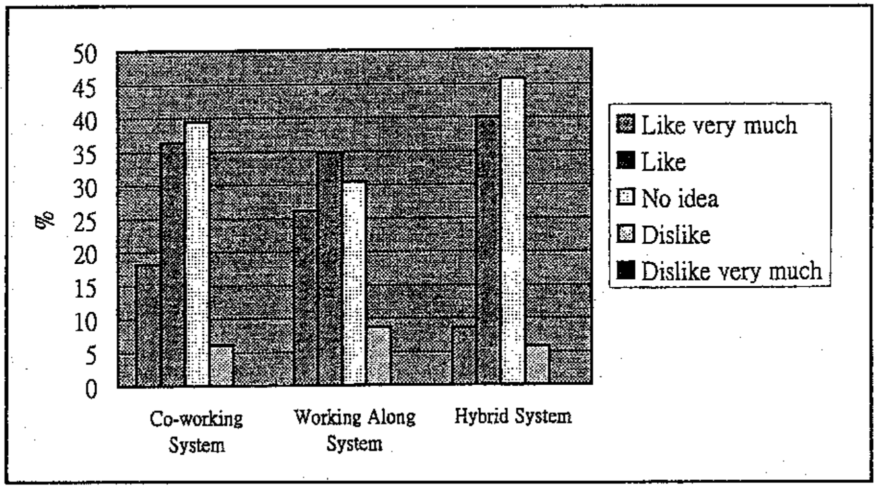


**Figure 10.** Statistics showing students' attitude toward the systems.

in communicating with others in the systems, they would probably prefer using other means to communicate. Hence, the result is rather encouraging. If, in the future, better communication media such as video-phones can be incorporated, it is almost certain that the students would accept the collaborating systems.

(b) *Can subjects successfully finish their work?* A second important question is whether the subjects can finish their work by using the systems. Thirty subjects completed this part of the questionnaire. Figure 11 displays the results obtained.

Figure 11 shows that over half of the subjects finished their work by using either one of the systems. All three systems were found helpful to at least half of the participants.

## CONCLUSION AND DISCUSSION

This study investigated the possibility of providing collaborative learning through the use of the Internet. The preliminary evaluation shows that the three collaborative models, namely, the Co-Working Model, the Working-Along Model, and the Hybrid Model, are all acceptable by the students and that students did finish their work by using the systems. Protocol analyses show that at least some students were using the expected ways to solve the problems.

The design of all the three systems were based on the assumption that collaboration will motivate students to learn and thus produce better learning results. As it may take longer for results due to collaboration to be achieved, a rigorous evaluation of the three systems should be done on a long-term basis to get students more accustomed to collaboration through the Internet and then benefit from using it. Results of the preliminary evaluation show that such a long-term evaluation is justified. The students liked using the systems and used them in the desired way even under the disadvantageous conditions that they were learning in normal settings and they were not good at typing into the computer. Our next step is, naturally, a long-term study of the effects of the systems.

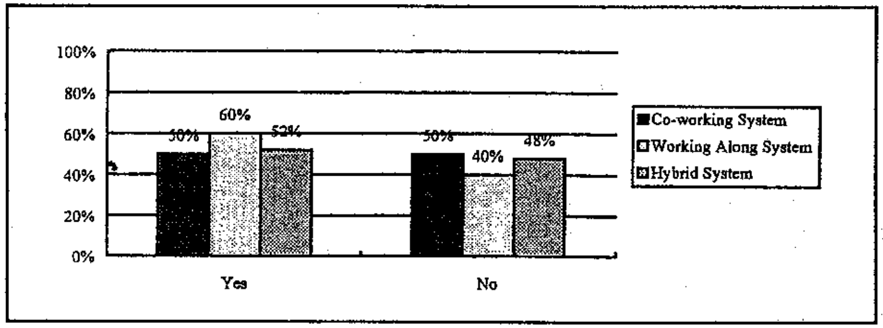


**Figure 11.** Percentages of students who can finish the problems by using the systems.



To make the system more practical to use, the following measures will be taken:

- Add intelligent agent: There is not always a learning partner available via the network. To provide a collaborative environment whenever a learner wants to learn, a possible solution is to develop a simulated learning companion at the other end of the network. A simulated learning companion is not a real person, but it should be able to act as a collaborative learner. Such a virtual companion can be made possible by using artificial intelligence techniques, and its effect should be contrasted with that of real learners before it can be put into real use.
- Add domain-dependent scaffolding tools: The system is now a bare-bone architecture in the sense that there is no domain knowledge incorporated to help students to formulate their solutions. In the future, appropriate scaffolding tools which provide students with terminologies and references should be provided in order to ease the students' cognitive load.
- Explore new collaborative learning models: The 3 collaborative models reported here are not the only possibilities. Further models, if found, will be added to the repertoire of models.

Different collaborative models would result in different learning outcomes, but it would be impractical to simply compare the effects produced. Various factors, such as the number of collaborative partners and the characteristics of the learners, al affect the results produced. It is thus hoped that in the future, these factors can be identified so that computer-aided learning, in particular collaborative learning, can be conducted more effectively.

## APPENDIX A
**Protocol of a Co-working Process**

| Line No. | Student | Dialogue | Response Category |
|---|---|---|---|
| 1 | S3: | You can see the Example, that is what we are required to do. | Identify Problem |
| 2 | S4: | How should we change the "xxx" in the program? | Ask Domain-specific Question |
| 3 | S3: | Can you work on that? | Ask General Question |
| 4 | S4: | No. | Answer General Question |
| 5 | S3: | Don't let me do everything . . ., you should do some more. | Make General Suggestion |
| 6 | S4: i | Understand *(acceptance)* | Accept General Suggestion |
| | *. . . (S4 coded)* | | |
| 7 | S3: | I'll show you an example, look at the screen. | Demonstration |
| 8 | S4: | I am sorry I still cannot do that. Besides, I have the example here too. | Admit Failure |
| *. . . (S3 coded)* | | | |
| 9 | S3: | Can you see what's changed | Ask Domain-specific Question |
| 10 | S3: | Do you wanna try? | Ask General Question |
| 11 | S4: | No. | Answer General Question |
| 12 | S3: . . . | Do you understand why? | Ask General Question |
| 13 | S4: | Yes, I understand. | Answer General Question |
| 14 | S4: | You are not that bad. | Show Emotional Support |
| 15 | S3: | Is there any place you don't understand? | Ask General Question |
| 16 | S4: | No. | Answer General Question |
| 17 | S3: | We can then go on with the Test | Make General Suggestion |
| *(The dyad then successfully passed the test)* | | | |



## APPENDIX B
**Protocol of a Work Along Process**

| Line No. | Student | Dialogue | Response Category |
|---|---|---|---|
| 1 | S5: | I think there should be a "new Thread" at the 12th line, What do you think? | Domain-specific Suggestion |
| 2 | S6: | Could you tell me how to do it? | Ask for Domain-specific Instruction |
| 3 | S5: | thread[i] = xxx -> thread[i] = new Thread[this] | Give Domain-specific Instruction |
| 4 | S6: | oh i see | Follow Domain-specific Instruction |
| 5 | S5: | and next line must start the 'Thread'. | Give Domain-specific Instruction |
| 6 | S6: | I got it | Follow Domain-specific Instruction |
| 7 | S6: | as well as the 20th line is same as the previous line, all right? | Domain-specific Suggestion |
| 8 | S5: | I think it should be "stop the thread . . .", What do you think? | Domain-specific Suggestion |
| 9 | S6: | Oh! u can try! | Domain-specific Suggestion |
| 10 | S5: | What is your progress now? | Ask General Question |
| 11 | S6: | I need your answer. Please press "Peer'sAmswer" | Ask General Question |
| 12 | S5: | No! It is you should press "Peer'sAnswer" if you want my answer. | General Response |
| *. . . (Each member worked on their own programs and occasionally checked the other's answers)* | | | |
| 13 | S5: | I think you are not very clear about the concept of "public void run ( )", do you want to think it over again. | Domain-specific Suggestion |
| 14 | S6: | Why? Could you give an example? | Ask Domain-specific Questions |
| 15 | S5: | You should call a method paint ( ) to repaint the canvas | Give Domain-specific Instruction |
| 16 | S6: | You are right. | Follow Domain-specific Instruction |
| *(S6 pressed peer Answer" to see S5's answer)* | | | |
| 17 | S6: | I think you probably have made a mistake at line 72, do you wanna check it again? | Domain-specific Suggestion |
| 18 | S5: | Do you know what is line 72 for? | Ask Domain-specific Question |

## APPENDIX B
(Cont'd.)

| Line No. | Student | Dialogue | Response Category |
|---|---|---|---|
| 19 | S6: | Let me first compile my program | General Suggestion |
| 20 | S6: | after new Thread, then start the Thread so : thread[i] = new Thread(this); thread[i].start( ); | Domain-specific Suggestion |
| 21 | S5: | Hmm . . . You're right, thanks for your reminder. | Show Gratitude |
| . . . *(Each member worked on their own programs and occasionally checked the other's answers)* | | | |
| 22 | S5: | 38th lines: Invalid expression statement. thread[i].xxx; thread[i].stop; 49th lines: Invalid expression statement. thread[i] xxx; thread[i] = null; | Domain-specific Suggestion; Domain- specific Suggestion |
| 23 | S6: | Hmm..You're right, thanks for your reminder. | Show Gratitude |
| . . . *(Each member worked on their own programs and occasionally checked the other's answers)* | | | |
| 24 | S6: | I think you are wrong at line 54 & 66, do you wanna check again? | Domain-specific Suggestion |
| 25 | S5: | should make the thread to "sleep" for 1 sec. | Domain- specific Suggestion |
| 26 | S6: | What is your progress now? | Ask General Question |
| 27 | S5: | oh well, i just have 2 errors | General Response |
| 28 | S6: | I think you probably still got some wrong concepts. Perhaps you should do the program over again. | General Suggestion |
| 29 | S5: | Hmm..You're right, thanks for your reminder. . . . I'll try it again. | General Response |
| 30 | S6: | Try "else if(evt.target == ckboxes[1] )" | Domain-specific Suggestion |
| 31 | S5: | Hmm..You're right, thanks for your reminder. . . . | Accept Domain-specific Suggestion |
| 32 | S5: | Oh thank god, we succeed! | Show Gratitude |
| 33 | S6: | It is pleasant to cooperate with u! | Show Gratitude |



## APPENDIX C
**Protocol of a Hybrid Process (a)**

| Line No. | Student | Dialogue | Response Category |
|---|---|---|---|
| 1 | S7: | Do you mind start first? Never mind the mistakes, just do it. | Give General Suggestion; Show Emotional Support |
| 2 | S7: | Do you know what do that mean at the 24th line? | Ask Domain-specific Question |
| S8 correct a mistake | | | |
| 3 | S8: | Any others? | Ask Domain-specific Question |
| 4 | S7: | I think this is just a trial to let you have some idea, but on the exception . . . why do you do that? I think you have made a mistake at the 45th line. | Show emotional support; Ask Domain-specific Question; Give Domain-specific Suggestion |
| 5 | S8: | Oh yes, thanks. | Accept Domain-specific Suggestion |
| 6 | S7: | I think this should be ta = new TextArea( ); what do you think? | Give Domain-specific Suggestion |
| S8 correct a mistake | | | |
| 7 | S7: | Do you know what "GenerateSpecifiedEsceotion" means? | Ask Domain-specific Question |
| S8 correct a mistake | | | |
| 8 | S7: | Perhaps I should test it at my terminal | Give General Suggestion |
| 9 | S7: | You must add a break to switch case; | Give Domain-specific Suggestion |
| 10 | S8: | Do you want to work on the co-working area now? | Give General Suggestion |

**APPENDIX D**
**Protocol of a Hybrid Process (b)**

| Line No. | Student | Dialogue | Response Category |
|---|---|---|---|
| 1 | S8: | Who wants to work in co-working area first? | Ask General Question |
| 2 | S7: | me first | Give General Suggestion |
| 3 | S8: | OK. | Accept General Suggestion |
| *(S7 coded in co-working area)* | | | |
| 4 | S7: | I have finished init( ); do you think if it is correct? | Ask Domain-specific Question |
| 5 | S8: | OK, i think it is OK, no problem. | Answer Domain-specific Question |
| 6 | S8: | My turn now? | Give General Suggestion |
| 7 | S7: | OK, no problem. You can write mouseDown( ) { }: | Accept General Suggestion; Give Domain-specific Suggestion |
| 8 | S8: | OK, no problem. | Accept Domain-specific Suggestion |
| *(S8 coded in the co-working area)* | | | |
| 9 | S8: | How did I do? | Ask General Question |
| 10 | S7: | in mouseDown( ) . . . I think you should add repaint ( ); | Give Domain-specific Suggestion |
| 11 | S8: | OK, no problem. But where should I add it? | Accept Domain-specific Suggestion; Ask Domain-specific Question |
| 12 | S7: | next to t.suppend( ); | Give Domain-specific Suggestion |
| 13 | S8: | Why i have to add repaint? | Ask Domain-specific Question |



**APPENDIX D**
**(Cont'd.)**

| Line No. | Student | Dialogue | Response Category |
|---|---|---|---|
| 14 | S7: | Because we want to clear the screen . . . and repaint ( ) will do update ( ) first; and update can clean the screen. . . . | Answer Domain-specific Question |
| 15 | S8: | Yes, I do think so too. | Accept Domain-specific Suggestion |
| 16 | S8: | It seems that we have just finished the work now. What do you think? | Ask General Question |
| 17 | S7: | I think it should be correct. | Ask General Question |
| (8 lines deleted here, the students discussed whether they should continue with their work) | | | |
| *(They tested their program and got 3 compiled errors)* | | | |
| 18 | S7: | Why? | Ask Domain-specific Question |
| 19 | S8: | I see one error that I know how to fix | Answer Domain-specific Question |
| 20 | S7: | Test again . . . | Give General Suggestion |
| *(Then they tested it five times and still got errors and then quit)* | | | |

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Direct reprint requests to:

Dr. Fong-Lok Lee
Department of Curriculum and Instruction
The Chinese University of Hong Kong
Shatin, N.T., Hong Kong