COMPUTATIONAL DESIGN PRINCIPLES TO SUPPORT THE MONITORING OF COLLABORATIVE LEARNING PROCESSES

C.A. Collazos,*,** L.A. Guerrero,* and J.A. Pino*

Abstract

Discussions of collaborative learning and its benefits have become common currency in many studies. Proponents argue that it promotes active learning, critical thinking, conceptual understanding, long-term retention of material, and high levels of student satisfaction. Despite this list of impressive potential outcomes and the attention it has received, many teachers are unclear as to what precisely is considered the impact of technology in the collaborative learning process. The authors present design principles intended to be useful to teachers in evaluating and monitoring the collaborative learning process. They outline design principles involving two aspects: the participation of the teacher during the collaborative learning process, and the inclusion of a strategy that generates conflicts among members of the group. They also describe the development of two software tools based on the principles they propose.

Key Words

Collaborative learning processes, CSCL, monitoring CSCL

1. Introduction

We live in an age that needs people who can collaboratively design, use, and maintain the tools of technology. Technology and teamwork will increasingly play a role in our lives. Children, adolescents, and young adults have no choice but to develop and increase their technological and teamwork literacy. There is no better place for them to start than in school. Learning in cooperative groups while utilizing the tools of technology should occur at all grade levels and and in all subject areas.

The value of cooperative learning has been recognized throughout human history. Organizing individuals to work in support of one another and putting interests of the group ahead of one's own are abilities that have characterized some of the most successful people of our time.

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Group learning, with its roots in ancient tribal customs, has traditionally been part of educational practice. Its effectiveness has been documented through hundreds of research studies [1–3]. The same cannot be said about technology-assisted cooperative learning; its effectiveness has yet to be proved. In particular, research is needed on the impact of technology on monitoring and evaluating collaborative learning.

Recent studies in CSCL refer to students' processes, whereas the teacher's or tutor's role has not been closely analyzed. In order to enhance learning, technology must promote cooperation among students and create a shared experience. *Technology-assisted cooperative learning* exists when the instructional use of technology is combined with the use of cooperative learning groups.

In this work we present design principles that we propose as useful tools for the design of applications that help teachers evaluate and monitor the collaborative learning process. In Section 2, we present some experiences on the use of technology in order to support collaborative learning. Section 3 presents the principles we propose. In Section 4 we describe two software tools we developed, and Section 5 presents some conclusions.

2. Some Experiences

In his description of the implementation of the Apple Classrooms of Tomorrow, Dwyer [4] notes that the cooperative, task-related interaction among students was natural and more extensive than in traditional classrooms. In such classes, students interact with one another while working at computers, spontaneously helping each other, showing curiosity about each other's activities, wanting to share what they had just learned to do, working together to build multimedia presentations about diverse topics, and combining their group's work into whole-class, interdisciplinary projects. The spontaneous cooperation often reported around technology both casts doubt on the individual assumption made by hardware and software designers and points towards the use of cooperative learning in technology-assisted instruction.

Richards *et al.* [5] have examined the use of cooperative, competitive, and individualistic learning activities at the computer. The studies included students from the eighth grade through college freshmen and lasted from 3 to 30 instructional hours. The tasks were a computerized navigational and map-reading problem-solving task and word-processing assignments. Computer-assisted cooperative learning, compared with competitive and individual efforts at the computer, promoted: (a) higher quantity of daily achievement, (b) higher quality of daily achievement, (c) greater mastery of factual information, (d) greater ability to apply one's factual knowledge in test questions requiring application of facts, (e) greater ability to use factual information to answer problem-solving questions, and (f) greater success in problem solving. Cooperation at the computer promoted greater motivation to persist on problem-solving tasks. Students in the cooperative condition were more successful on operating computer programs. In terms of oral participation, students in the cooperative condition, compared with students in the competitive and individualistic conditions, made fewer statements to the teacher and more to each other, made more task-oriented statements and fewer social statements, and generally engaged in more positive, task-oriented interaction with each other (especially when the social skill responsibilities were specified and group processing was conducted). Finally, the studies provided evidence that students were perceived to be of higher status in the cooperative than in the competitive or individualistic conditions [1, 5, 6].

In addition to Richards' work, there are a number of studies reporting better learning for students using a combination of cooperative learning and computer-based instruction than the learning obtained by using computer-based instruction while working individually (see [7–10]). Other studies have also shown that introduction of computers into classrooms increases cooperative behaviour and task-oriented verbal interaction [11, 12]. Most students seem to find it fun, enjoyable, and effective to use computers collaboratively with classmates. Students are more likely to seek each other out at the computer than they normally would for other school work. Even when students play electronic games, they prefer to have partners and associates. The computer may not only be a good tool to cooperate, but also be a good agent to introduce cooperative learning in schools.

When collaboration is mediated via a computer system, the design of this system affects the collaborative process. This mediation has methodological advantages: the experimenter may have explicit control over some aspects of collaboration. The effects of the computer as medium also have pedagogical aspects: to support the type of interactions that are expected to promote learning. Dillenbourg mentions three settings in which the computer influences collaboration: two human users collaborating on a computer-based task, computer-mediated collaboration, and human-computer collaborative learning [13].

3. Design Principles

In this section, we describe our principles, which are intended to help teachers monitor and evaluate the learning process during a collaborative activity. It is still common to present knowledge acquisition from a rather traditional point of view. Pea and Gomez describe this so-called transmission model as follows: an expert, for example a teacher, is the source of knowledge, and this person provides the student with his or her knowledge. Transfer of knowledge only takes place when the teacher comes into operation. Consequently, the extent to which students gain insight depends on the quality of this transmission. The transfer of teacher's knowledge becomes crucial, whereas the role of the recipients of this knowledge is merely receptive [14]. This scenario ignores the possibility that students may acquire knowledge by a constructive and active learning process. This latter type of knowledge acquisition requires a student's active role; they need to learn to learn (metacognitive abilities).

Underlying nearly all collaborative learning experiences is a distinctive set of assumptions about what teaching is, what learning is, and what the nature of knowledge is. Perhaps the most pivotal of these is the assumption that knowledge is created through interaction, not transferred from teacher to student. Hence, it typically—and logically—follows that instructional activity must begin with students' current levels of background knowledge, experience, and understanding. It also follows that the teacher's role is to create a context in which learners can make the material their own through an active process of discovery [15]. Consequently, our principles include two aspects: the participation of the teacher during the collaborative learning process, and the inclusion of a strategy that generates conflicts among members of the group. We will explain in detail each of these aspects.

The first aspect is concerned with the participation of the teacher during the process of the collaborative learning activity. According to Johnson and Johnson, one of the most important aspects of collaborative learning is to "monitor students' learning and intervene within the groups to provide task assistance or to increase students' interpersonal and group skills" [16]. A teacher systematically observes and collects data on each group as it works. When assistance is needed, the teacher intervenes to assist students in completing the task accurately and in working together effectively.

A tutor is needed to structure the process, to give advice when needed, and to promote deepening understanding. If students and tutors are communicating mainly through a computerized learning environment, tutors have to learn new ways to support students.

One way of assessing the effectiveness of the groups is to monitor and observe the members' interactions as they work together. Observation gives the teacher an understanding of the quality of each group's interaction and its progress on the assignment. In the model we propose, the teacher not only can observe the interactions among members of the group, but also can intervene anytime she or he considers it is necessary. In this way, the teacher can become another member of the group. It is important to note that this kind of intervention is invisible for the members of the group, in the sense that even if participants know the teacher is observing them, they can only interpret every act of the teacher as a hint that the system gives to them.

While observing students working with computer applications, teachers can see the choices students are making on the monitor, ask questions regarding students' learning goals and decision making, and make suggestions for revisions when needed. With this model, applications can be designed to provide a window to the ways in which students construct meaning—their misconceptions, conjectures, and the connections they make among ideas [17]. Teachers can use this information to revise and refine instruction.

The role of the teacher(s) is to maintain the focus of the discussion, guiding students through the knowledge-constructing process. The assumption is that both the contents and the pattern of the sequence of messages reflect the degree of collaborative learning. In this aspect, the point is not to provide the right answer or to say which member of the group is right, but to perform a minimal pedagogical intervention (e.g., provide some hint) in order to redirect the group work in a productive direction or to monitor which members are left out of the interaction [18].

In order to satisfy the aspects mentioned above, it is necessary to clarify how and when the teacher must intervene. Table 1 includes a set of situations the teacher must consider when she or he is monitoring the process during collaborative work.

Table 1
Set of Situations the Teacher Must Monitor

Situation
One of the members of the group solved the problematic situation.
One of the members of the group does not understand the problematic situation.
One of the members of the group is performing an incorrect action.
There are many "conflictive situations" and the members of the group are not capable of handling them.
There are no "conflictive situations."
Members of the group do not send any kind of messages.
A great percentage of the messages that one of the members of the group is sending are not related to the solution of the problem.

The second aspect is to realize that some conflict is perhaps inevitable—and maybe even desirable. Part of what students are learning in a group project is how to negotiate differences and deal with other people to reach a common goal. Groups sometimes become stronger as they work through the conflicts that arise with the clash of different ideas and work habits. As Miller, Trimbur, and Wilkes point out, "excessive conflict can certainly interfere with performance. Paradoxically, excessive harmony can do the same, because members of the best groups tend to be critical of one another's work or at least to tolerate an in-house critic; they tend also to impose high standards on themselves" [19]. Of course, this kind of creative tension does not worry most teachers as much as the potential personality conflicts that sometimes cause bitter feelings and unproductive groups. For this reason, our model includes a scheme that creates conflicting conditions among members of the group.

The notion of conflict is the basis of the social-cognitive theory of human-to-human collaboration [20]. According to this theory, the benefits of collaborative learning are explained by the fact that when two individuals disagree at some point, they feel a social pressure to solve that conflict, and the resolution of this conflict may lead one or both of them to change their viewpoint. This can be understood from the "multiplication" perspective, because a conflict between two or among several agents is originated by multiplicity of knowledge. It appears, however, that learning is not initiated and generated by the conflict itself but by its resolution, that is, by the justifications, explanations, and so forth, that lead to a jointly accepted proposition.

It would be useful if learners were able to share doubts, questions, and comments among themselves, as in such sharing process they have to be able to reflect about the topic under study and to clearly express their reasoning. Such abilities development is one of the benefits of collaborative learning that individual learning does not address. It is important to consider how to deal with conflicts. As we have mentioned, some conflicts arise out of the fact that students do not necessarily know how to work in groups. After years of developing individual skills in competition, students need to learn how to trust other group members, how to delegate, how to negotiate, and many other team skills. Helping students understand group dynamics can also prevent conflicts. Miller *et al.* identify personality characteristics and learning styles as two areas that shape the dynamics of the group, and encourage teachers to accommodate these differences by providing groups with ways of dealing with conflict as it arises. They argue that although educating students about group processes takes class time that might be spent on course content, spending a class period discussing group work skills can make a major difference in the success of the project: "We should teach the skills that we are grading. Thus, such a session should include a briefing on the necessity for and logistics of good communication and organization and give participants an opportunity to discuss the various kinds of talents and individual differences or preferences that different people bring to tasks" [19]. They suggest activities such as small groups solving a simple puzzle and reflecting on the group process afterwards, students role-playing group interaction and discussing scenarios as a class, or reading and discussing information about the characteristics of different work styles and personality types, and how to accommodate these differences.

No matter how well you prepare, however, variables outside your control ensure that conflicts will sometimes occur. Keeping in touch with the progress of the groups—through periodic progress reports or team assessments, for example—allows you to identify problems within the groups as they arise. If a group is having trouble resolving a problem, you will want to decide how active a role you are willing to play to help your students handle the situation.

The process of confrontation and conflict among members of the group, rather than being viewed as a disadvantage, brings about fundamental cognitive restructuring [21]. Brown and Palicsar note the important role of the skeptic in group discussions: "by forcing the group to defend or elaborate solutions, a more mature resolution will emerge" [22]. They also argue that situations that encourage dissatisfaction with the existing state of knowledge tend to foster conceptual change. Environments that encourage questioning, evaluating, and criticizing the status quo are considered to be fruitful breeding ground for restructuring knowledge.

In the study of computer-supported collaborative learning, some researchers aim at constructing systems that could automatically monitor collaboration. Inaba specifies a model to define (1) which opinion is being negotiated, (2) what is the focus of a contribution of each participant, and (3) what is the degree of involvement that each participant has in the discussion process [23]. Other studies describe the monitored actions and interactions as a "discussion graph." However, Stahl mentions that collaborative knowledge learning is a complex and subtle process that cannot adequately be reduced to a simple graph or coding scheme [24].

In summary, a design principle we propose in order to be a useful tool for the design of applications that help teachers to facilitate evaluation and monitoring of the collaborative learning process must include the participation of the teacher during the collaborative learning process. It must also include a strategy that generates conflicts among members of the group and a mechanism to record every message sent by the members of the group. In the next section, we describe two software tools we have developed based on these principles: MemoNet and Color Way.

4. Software Tools

4.1 MemoNet

This game is loosely based on the classic "Memorize Game," the goal of which is to find the equal pair within several covered cards. This is repeated successively until there are no covered cards remaining. In the case of MemoNet, the idea is that four people try to find four equal cards from an initial set of ten different cards. All players have the same set of cards but ordered in different ways. A person draws one card each time. So, they need to collaborate in order to solve the problematic situation. The card is removed when the four players have found it. The game continues until all cards are uncovered. The game is played in a distributed fashion, with communication allowed through a chat tool.

Fig. 1 illustrates the game user interface. In this one, we can see the messages sent by the different users through chat. Also, we can observe the various actions performed by the other users: Santiago has selected the two of diamonds; Alexander the nine of diamonds; Felipe the ten of diamonds, and Juan the two of diamonds.

When a user clicks on a card, this one turns and appears as illustrated in the figure. Once four cards have been chosen, a button will appear with the "Next" label. If it is depressed, two events will occur: (1) If no success, all the cards will be given back; (2) If success, the cards will disappear from the screen. Because each participant has a partial view of the game, the player must interact with his/her peers to solve the problem. In this way, participants need to collaborate in order to solve the problematic situation.

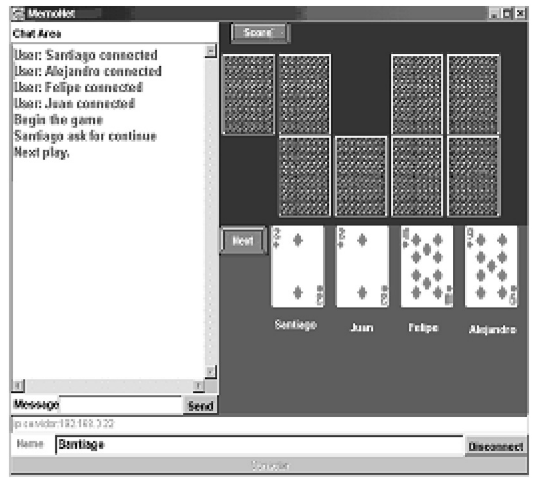

Figure 1. User interface of MemoNet.

It is important to note that all the actions performed by the users are recorded in a log. The application records each message sent by any member of the group. Along with the message, it registers the time of occurrence and sender. The tool also registers the start and finish time of the game.

4.1.1 Teacher Interface

Fig. 2 illustrates the teacher interface. In the chat area it is possible to watch all the messages sent by the players. Players can send a message to any or all of their peers. Also, we can observe in the data area the letter selected by each player in the last play.

Messages sent by the teacher to the players are written on an independent window. They appear to the receiver as mechanical alerts of the program to a particular fact, similar to the "paper clip" of Aid service of Microsoft Word. An alert message unfolds as shown in Fig. 3.

4.2 Color Way

The second game is called Color Way. The game has a 6×4 board of coloured squares. Each player can see his or her own obstacles (with his or her colour). Each player has a token with her or his colour, and this token can progress from the lower row to a target located on the upper row. The player can move the token using the arrows and back buttons only through grey squares, which are not currently used by another token. Another restriction to movements is given by the progress of the other's tokens: no token can go to row n if there is a token in row $n-2$. In a similar way as MemoNet, this game provides communication through chat.

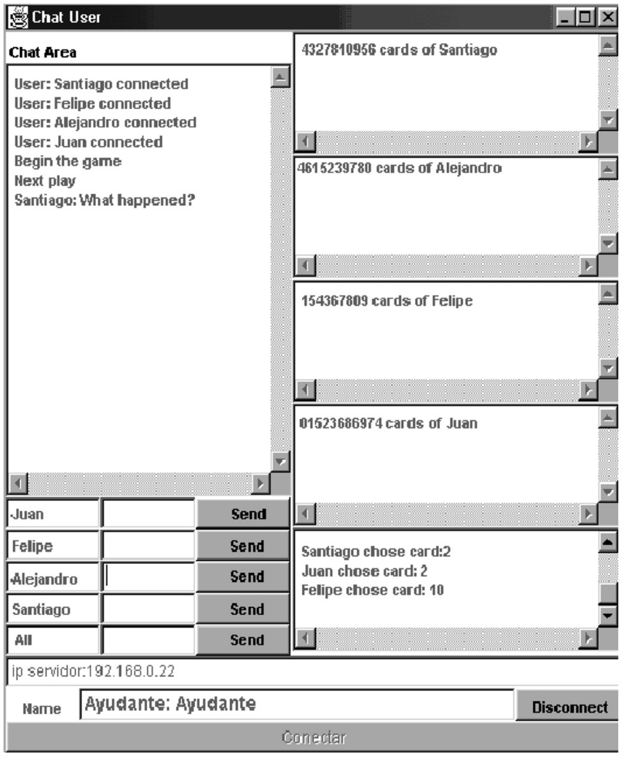

Figure 2. Teacher's user interface of MemoNet.

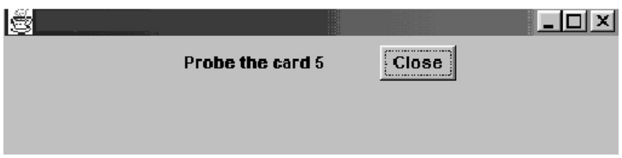

Figure 3. Teacher's message.

In order to move the piece that corresponds to every player, which is seen by its assigned colour, the player must click one of the arrows indicating the direction of the movement. The button labeled "Back" must move backwards as a result of a wrong movement. Fig. 4 shows the chat zone with some comments of players. Also, we note that the green player (second column) moved and has to wait until the other player moves. In this way, they need to collaborate in order to find each level solution. We also see that when backing down, the player Felipe reduces his score by five points. This happens whenever some player backs down; only the score of the player who backed down is reduced.

4.2.1 Teacher Interface

Fig. 5 illustrates the teacher interface. In the chat area it is also possible to watch all the messages sent by players. Again, the teacher can send a message to an individual player or to all of them. In the data area it is possible to see the grid of each player, and the displacements that each one of them has made. Messages sent by the teacher to the players are written on an independent window. They appear to the receiver as mechanical alerts of the program to a particular fact, similar to MemoNet. An alert message unfolds as shown in Fig. 6.

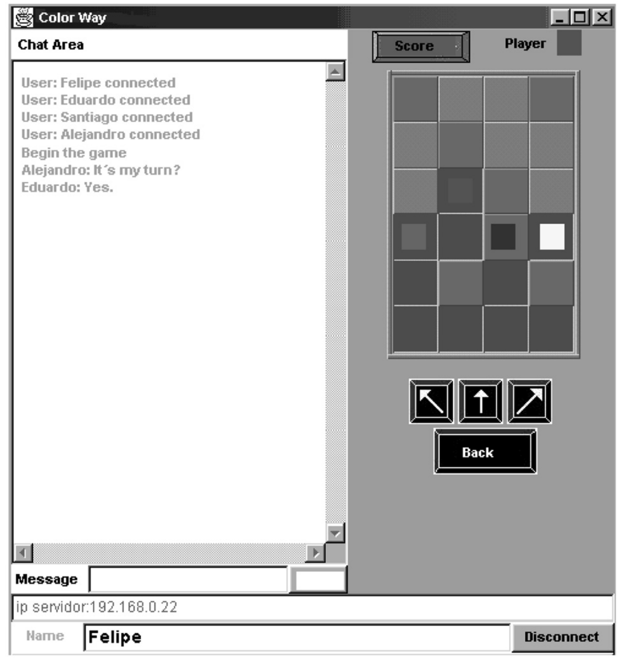

Figure 4. User interface of Color Way.

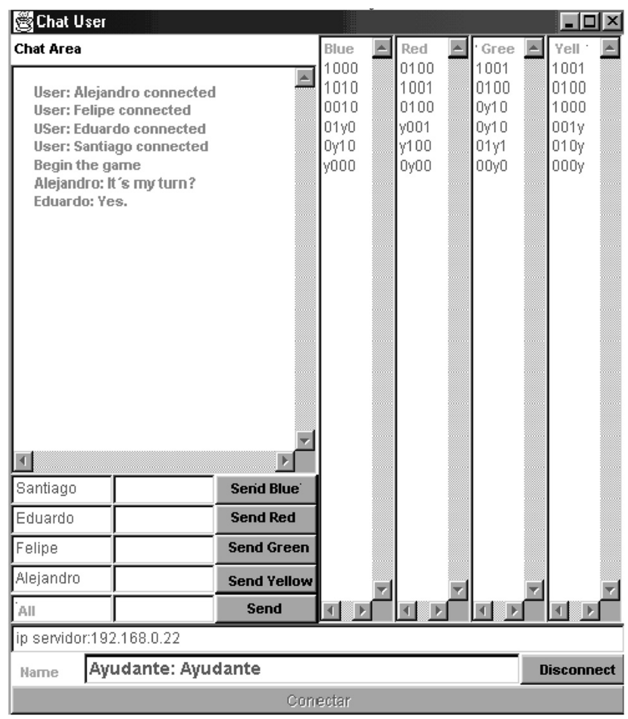

Figure 5. Teacher's user interface of the Color Way.

Figure 6. Teacher's message.

5. Conclusion

We have presented computational design principles in order to support collaborative learning monitoring and evaluation. This is based on two elements: participation of the teacher during the collaborative learning process, and the inclusion of a strategy that generates conflicts among members of the group. Common sense says that what one really needs for effective CSCL is a good, reliable, appropriate, and—if possible—semi-intelligent technology. Although we do not deny the importance of these technological qualities, we argue that it is necessary to include other aspects related to the monitoring and evaluation of the collaborative learning process.

In order to monitor and regulate the interaction among members of a group, the teacher retains a role in the success of collaborative learning. This role is often named "facilitator" instead of "tutor" because the point is not to provide the right answer or to say which group members are right, but to perform a minimal pedagogical intervention in order to redirect the group work in a productive direction or to monitor which members are left out of the interaction. Also, conflicts are an inherent part of collaborative interactions. In such cases, articulating the conflicts can be a way to refine solutions, avoid group-thinking, and so on. In the educational scenario, Doise and Mugny's theory of social-cognitive conflict [20] also emphasizes the importance of conflict as a promoter of cognitive development. These conflicts are socially constructive processes. They may involve confrontation, which helps in knowledge restructuring. They may promote reflective or metacognitive thinking. For this reason, our principles involve the participation of the teacher during the collaborative learning process and inclusion of a strategy that generates conflicts among members of the group.

The principles we propose could generate controversial activities. This kind of controversy induces a greater motivation to learn, promotes higher achievement as learners work harder to win their points, and because it involves the learners it increases knowledge retention.

Also, with the design principles we propose, the teacher promotes student learning by helping, sharing, and encouraging efforts to learn. Students explain, discuss, and teach what they know to others. The peer coach also benefits by having to conceptualize and explain procedures to others. Students can gain from both providing suggestions and receiving answers from teachers and teammates. These processes can develop cognitive skills by encouraging explainers to clarify and reorganize materials, recognizing and filling gaps in understanding, developing new perspectives, and constructing elaborate conceptualizations.

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