A Framework for a Computer System to Support Distributed Cooperative Learning

CHIUNG-HUI CHIU AND CHIH-CHAO HSU

National Tainan Teachers College, Taiwan, Republic of China
cchui@ipx.ntntc.edu.tw

To develop a computer system to support cooperative learning among distributed students, developers should consider the foundations of cooperative learning. This article examines the basic elements that make cooperation work and proposes a framework for such computer supported cooperative learning (CSCL) systems. This framework consists of five main components to support cooperative group structures, cooperative task structures, cooperative incentive structures, cooperative space structures, and individual accountability structures. To further guarantee successful cooperative learning, the mechanics to teach or reinforce appropriate cooperative skills should be added. This article provides concrete guidelines to the developers of CSCL systems.

Shaped by Vygotsky’s theory (Vygotsky, 1978, 1981) as well as situated cognition (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), stressing the social dimension of the construction of knowledge, many effective approaches have been developed to exploit the potential of social interaction for enhancing learning and performance in school. Cooperative learning has been one of the most recommended methods. It is the instructional use of small groups so that students can work together to maximize their own and each others’ learning (Johnson, Johnson, & Smith, 1991a; Johnson, Johnson, & Smith, 1991b). With the exponential growth of the Internet, such cooperative learning can be activated among students not necessarily in the
same room or at the same time. They can cooperate with any geographically separated person whenever they like. The attributes of time- and place-independent communications make group interaction and cooperation in this medium distinctive. Many educators have shown enthusiasm for distributed cooperative learning (Harasim, 1994). Although cooperative learning on the Internet has been experimental and not practicable in school education thus far, it is foreseeable that this will gradually become practical and even widespread in education once the supporting systems are mature and widely available. Many have been devoted to the development of such computer supported cooperative learning (CSCL) systems. However, numbers of developers claim their systems support “cooperative learning,” but only collaboration—not cooperative learning. This makes developing a framework for a CSCL system desirable because an incorrect design can lead to an unhelpful system and the development time expended would be wasted. This article proposes a concrete framework for CSCL systems. To understand what the framework for a CSCL system should incorporate, the basics that make cooperative learning work are examined first.

ESSENTIALS OF COOPERATIVE LEARNING

For several years, many studies have attempted to measure and understand the effects of cooperative learning. This research has extensively shown the effects on student achievement, attitudes, self-esteem, inter-group relations, acceptance of academically handicapped students, and the ability to work collaboratively (Johnson & Johnson, 1989; Johnson & Johnson, 1994; Slavin, 1991b). Johnson and Johnson (1989) analyzed high-quality studies selected from 375 studies conducted over the past ninety years and found that cooperative learning tends to promote higher achievement and more positive attitudes toward the subject area, instructional experience, and continuing motivation to learn more for all age levels, all subject areas, and a variety of tasks.

While a majority of research has shown that cooperative learning is often efficient, some studies produced contradictory evidence. Slavin (1991b) reviewed 67 studies which evaluated the influence of various cooperative learning methods for periods of four weeks or longer and found that 41 (61%) had significantly greater achievement in cooperative classes; there were no differences in 25 studies (37%); and the control group outperformed
the cooperative group in one study. Tateyama-Sniezek (1990) reviewed 12 studies comparing cooperative learning to individual instruction and found only 6 reported significant results favoring cooperative learning. Not all forms of collaborative learning appear equally effective for all goals. This discrepancy led researchers to seek conditions under which collaborative learning appears to be effective. A wide range of conditions or independent variables have been studied. These conditions can be clustered into four categories, including positive interdependence, face-to-face interaction, individual accountability and cooperative skills. Many researchers regard these four as essential elements of cooperative learning (Johnson & Johnson, 1989; Johnson, Johnson, & Holubec, 1993; Johnson, Johnson, Holubec, & Roy, 1984).

Positive Interdependence

Positive interdependence is the heart of cooperative learning (Johnson & Johnson, 1989, 1992a, 1992b). Positive interdependence is the perception that one is linked with others in a way that one cannot succeed unless the group succeeds (Johnson & Johnson, 1992a), that is, the awareness that they sink or swim together. This promotes a situation in which students work together in small groups to maximize the learning of all members, sharing their resources, providing mutual support, and celebrating their joint success.

Interdependency can be established through: (a) mutual goals, (b) joint rewards, (c) shared resources, (d) complementary roles, (e) divided tasks, and (f) group identity. Mutual goals and joint rewards would unite diverse students into a common effort to achieve group goals and thus provide students with an incentive to help and encourage one another (Johnson & Johnson, 1989; Slavin, 1993). Typical methods are: (a) rewards based on integrated individual accomplishments, and (b) rewards based on group final products (Watson, 1992). Group rewards are likely to have positive or neutral effects on increasing motivation and performance (Hooper & Hannafin, 1991; Slavin, 1984, 1991a). However, group rewards might decrease performance once the problem of responsibility diffusion occurs (Slavin, 1983). Shared resources, complementary roles, and divided tasks are ways for group members to accomplish their mutual goals and attain their joint rewards. If each member has only a portion of the information, materials, and resources necessary for the task to be completed, the group must
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combine member resources to achieve its goal. If group members are assigned complementary and interconnected roles (such as reader, checker, encourager, and elaborator; or astronomer, meteorologist, historian, and geologist), and labor is divided among group members, a group member cannot complete the group task except through other members fulfilling their responsibilities. Thus shared resources, complementary roles, and divided tasks lead individuals to recognize that the accomplishment of group members is mutual (Johnson & Johnson, 1992a). Group identity would define the interests, values and nature of the group and unite the group members. Group identity can be established through a group name, symbol, or meeting area (Brush, 1998; Johnson & Johnson, 1991), or by constructing a competitive environment among groups (Aronson & Patnoe, 1997; Johnson & Johnson, 1991; Miller & Harrington, 1992; Slavin, 1995).

**Face-To-Face Interaction**

In a cooperative learning situation, group members work together to achieve some goals, complete assignments, and promote one another’s success. Members are expected to meet face-to-face to provide one another with efficient and effective help and assistance, exchange needed information or materials, discuss the concepts and strategies being learned, decide how to solve problems, and encourage and support one another’s efforts to learn (Johnson & Johnson, 1992a; Johnson & Johnson, 1994). Face-to-face interaction will not only avoid ambiguity and promote richness in communication, but also help build personal relationships (Johnson & Johnson, 1994; Graves & Graves, 1985).

Face-to-face interaction is easy to achieve. Typically, students are positioned toward one another for direct eye-to-eye contact and face-to-face conversations (Stahl, 1994). Therefore, the conventional classroom in which students’ desks are arranged in long, straight rows is inappropriate. The class environment should be restructured, for example, students arranged in groups with individual desks facing inward in small clusters throughout the room (Graves & Graves, 1985). Johnson and Johnson (1994) suggested that to obtain meaningful face-to-face interaction, the size of the groups should be as small as two to four members.
Individual Accountability

Individual accountability means that students must be held individually responsible and accountable for doing their share of the work and for mastering the targeted content and skills (Aronson & Patnoe, 1997; Brush, 1997; Slavin, 1995). Researchers generally agree that individual accountability is essential if cooperative learning is to increase achievement (Watson, 1992). If individual accountability is structured into cooperative learning activities, it will ensure that group members know who needs more assistance, support, and encouragement, and know that they cannot “hitch-hike” on the work of others (Johnson & Johnson, 1994). Cooperative learning will then have its greatest effects as Slavin (1983) pointed out after reviewing cooperative learning research.

Common ways to incorporate individual accountability into cooperative learning include arranging for group members to have exclusive roles and look into whether students function properly; having members perform unique tasks in order to complete an overall group project and evaluating students based on unique tasks (Slavin, 1983); giving individual exams to each member or a randomly selected member and holding the group accountable for the results (Aronson & Patnoe, 1997; Johnson & Johnson; 1975; Slavin, 1995); or determining individual grades based on peer evaluations of all group members (Slavin, 1995).

Cooperative Skills

Contributing to the success of a cooperative effort requires cooperative skills (Johnson & Johnson, 1994). Students need cooperative skills to work effectively with the other members of their group. Cooperative skills include providing leadership, respecting one another, communicating ideas, reaching a shared decision, and managing conflicts (Archer-Kath, Johnson, & Johnson, 1994; Aronson & Patnoe, 1997; Hill & Hill, 1990; Johnson & Johnson, 1990, 1991, 1994; Johnson et al., 1991a). It has been found that cooperative skills not only promote higher achievement, but also contribute to building more positive relationships among the group members (Putnam, Rynders, Johnson, & Johnson, 1989).
Many students have never worked cooperatively in learning situations and lack the needed interactive skills. Merely placing students in groups and expecting them to cooperate does not mean that students will automatically use these skills. As Johnson and Johnson (1991) stated, “students who have never been taught how to work effectively with others can not be expected to do so.” Theorists and researchers (such as Brush, 1998; Johnson & Johnson, 1994; Slavin, 1995) suggested that these skills have to be taught just as purposefully and precisely as academic skills. Teachers may need to show these expected skills to students and provide opportunities for students to practice them prior to starting cooperative learning activities (Aronson & Patnoe, 1997; Sharan & Sharan, 1992). During the cooperative learning activities, prompts could be given to remind students to use cooperative skills (Kagan, 1985; Sherman & Klein, 1995; Slavin, 1995). Teachers may give bonus points or feedback to individual students or cooperative groups if students practice the targeted skills (Johnson & Johnson, 1990, 1991). Another strategy is to have students reflect on their use of cooperative skills after a cooperative work period (Aronson & Patnoe, 1997; Johnson & Johnson, 1994; Sharan & Sharan, 1992). Teachers may have group members discuss what member actions are helpful and unhelpful and make decisions about what to continue or change. An alternative approach is to have members individually respond to a checklist for cooperative skills usage (Aronson & Patnoe, 1997). Such reflection will enable learning groups to focus on group maintenance, facilitate the learning of cooperative skills, ensure that students receive feedback on their participation, and reinforce the consistent practice of cooperative skills (Johnson & Johnson, 1994). In addition, Johnson and Johnson (1990, 1991) suggested that an individual or group award be used to reinforce skills usage.

**FRAMEWORK OF CSCL SYSTEMS**

As previously discussed, simply having students work in small groups will not guarantee academic or social benefits (Johnson, et al., 1993). Educators must implement the basic elements that make cooperation work in their instructional strategy. This will definitely not be an easy task (Brush, 1998; Tateyama-Sniezek, 1990). Stahl (1994) claimed that unless these elements are used frequently and correctly, teachers should not expect the many positive long-term results from cooperative learning that can be achieved. The
Internet technology certainly does not incorporate any inherent cooperative learning elements. To make use of the Internet to support a cooperative learning activity among distributed students; a special computer system built on the Internet is required. In addition, this system must incorporate the four essentials of cooperative learning into its design. However, these elements, such as positive interdependence, are too vague to be directly converted into a system design for most developers. After the experience of developing a CSCL prototype system, these four elements are decomposed into the following more concrete components: cooperative group structure, cooperative task structure, cooperative incentive structure, individual accountability structure, cooperative space structure, and cooperative skills instruction. Figure 1 represents the relationship between the components of CSCL systems and the essential elements of traditional cooperative learning.

**Figure 1.** Relationship between components of CSCL system and elements of cooperative learning

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**Cooperative Group Structure**

The first thing teachers have in mind to implement cooperative learning is having students work in small groups. How to support a cooperative group structure is an important consideration for developing a CSCL system. Cooperative group structure involves the size, the composition, and the period of activity for the learning groups.
Small groups seem to function better because the members can interact more intimately and become cohesive. In a large group, some members tend to “sleep” or become excluded from the interactions (Mulryan, 1992; Salomon & Globerson; 1989). Harasim and Riel (Harasim, 1993; Riel & Harasim, 1994) suggested three to five persons as the preferred group size for a network mediated activity. Seven to fifteen groups are appropriate since the aggregation is then big enough to provide a variety in thought and approach.

The composite members of a group should be heterogeneous in age, gender, race, intelligence, development, performance, attitude, and leadership (Riel & Levin, 1990; Watson & Marshall, 1995). If the members are grouped from distant locations, satisfying this condition will usually not be a problem. To assist in the establishment of interdependency, specific roles can be designed and designated to group members. In addition, a unique name or symbol can be given to a group to create the feeling of a group identity and further interdependence (Brush, 1998; Johnson & Johnson, 1991).

It is usually recommended that groups should be reorganized and roles for group members be reassigned after an activity has been completed (Brush, 1998). This would provide each student with the opportunity to cooperate with diverse persons and perform different roles. However, it should be noted that many of the positive affective, social skills, attitudes, and academic benefits of cooperative learning tend to emerge and are retained only after students have spent four or more weeks together in the same heterogeneous group.

A CSCL system should support structuring groups based on size, composition, and long-term aspects. A CSCL system should help with generating and arranging groups according to appropriate (or teacher designated) group size and group numbers for a cooperative learning activity. To sustain heterogeneity, the system could prevent students at the same location from forming the same group or even the same group aggregation. The segregation can be implemented through distinguishing the IP addresses of the computers students use. In a group, the system should help with group members or conditionally allow group members to select complementary roles (each can execute some specific function). For each generated group, the system can assign or allow students to decide on a name or symbol. The system should restrict students from attending several groups involved in the same activity, or changing roles in the middle of the activity. The system should also help with preventing a student from always having the same
role. This can be achieved if the system traces student role status throughout the activities.

Cooperative Task Structure

Classroom cooperative learning always includes a cooperative task structure (Slavin, 1986). The cooperative task structure is a way to establish positive interdependency (Aronson & Patnoe, 1997). Cooperative task structures are situations in which two or more students are allowed, required, or encouraged to work together toward the completion of some task. To complete the task, group students must coordinate their efforts. Two task structures are commonly used: task specialization and group study (Watson & Marshall, 1995). In task specialization, each group member is given responsibility for a unique part of the task. In group study, all members of a group work together and responsibility is not rigidly separated. Task specialization helps insure that all members participate because certain responsibilities are given to each, while group study causes all members to study and become equally familiar with the same information (Slavin, 1983).

A CSCL system should support either or both cooperative task structures. For task specialization, the system should help divide resources and tasks among the group members and associate the divided resources and tasks to particular members so that each member has unique responsibilities needed for completing the overall group assignment. These unique responsibilities among group members can be equivalent. For example, the system could designate each member to manage a portion of the materials or play the same role (Denning & Smith, 1997) and require them to teach, explain, or help one another. The unique responsibilities among group members can be complementary. For example, one member is designated to read and summarize information, a second group member is designated to record and review information with the group, and so forth. The system could let the teacher decide how to divide the tasks among the group members. For group study, the system should allow separated group members to access and manipulate shared objects, such as a document, image, or spreadsheet. The shared objects involved in a group study task are subject to concurrent access and real-time constraints. To satisfy these conditions, CSCL system developers could refer to concurrency control algorithms in the domain of distributed real-time groupware for solutions (Ellis & Gibb, 1989; Karsenty & Beaudouin-Lafon, 1993).
Collaborative Incentive Structure

Most cooperative learning tasks carry a cooperative incentive structure. An incentive structure is a way of motivating students to perform and continue the learning task (Slavin, 1983). A cooperative incentive structure can provoke two or more individuals to become interdependent for a joint goal or reward. The typical method for establishing cooperative incentives in a traditional classroom is rewarding the group (Watson, 1992). In theory, rewarding a group based on group performance should create group norms and peer sanctions favoring high performance (Slavin, 1984; 1991a). Hooper and Hannafin (1991), Slavin (1984) according to a research review, and Watson and Marshall (1995) found that group rewards are likely to have positive or neutral effects on increasing motivation and performance. Hooper and Hannafin (1991) further found that learners in group reward situations cooperated more frequently than learners in individual reward situations. To establish collaborative incentive structures, a CSCL system should be able to trace group activities concerning group members’ connection, interaction, devotion, cooperation, progress, work contribution, and produced works. The data could then serve as the base for providing group rewards. Ideally, the system should provide teachers with methods for analyzing the group data. The system could present the analyzed results to group members and all participants in written graph/chart form as feedback and praise. This would further strengthen incentive since group members would favor high accomplishment.

Individual Accountability Structure

While applying a cooperative incentive structure, the problem of responsibility diffusion should be avoided (Slavin, 1983). The way to decrease the opportunity for diffusion of responsibility is individual accountability (Slavin, 1983; Watson & Marshall, 1995). Individual accountability exists when the performance of each individual is assessed and the results relayed to both the group and the individual (Johnson et al., 1991a). To incorporate individual accountability, a CSCL system could include the following designs. First, the system could have individuals perform unique functions and tasks, or access and comprehend specific materials but restrict other members from accessing or undertaking the work. Individual accomplishment could be traced by the system automatically or through peer evaluations by group members. Second, short tests could be embedded after or
during the cooperative work, with the requirement that each member or a randomly selected member in the group take the tests individually. The test items must be aligned directly with the content focus of the learning tasks. The system could have functions to assist in collecting and managing the test items. It should be noticed that network channels allowing for communication and assistance among the group members should be blocked during test implementation. Third, individual task accomplishment and test results should be used in the overall assessment of the group. Individual grades could be determined based on individual test results, peer evaluations by group members or the required individual unique tasks. Ideally, the system should have the ability to track individual progress through all activities and individual tests. This would allow precise decisions on how the individual performance is accountable for the over all group performance. Methods for analyzing the data from each member could be embedded. The system could feedback the results to each group member. This would remind group members to take their responsibilities to the group seriously.

Cooperative Space Structure

To carry out cooperative learning, a physical space for face-to-face interaction is required (Graves & Graves, 1985). To support cooperative learning among geographically distributed students; a CSCL system must enable such interaction. In fact, the advancement of technology not only makes “face-to-face” communications possible, but can also support various interaction paradigms. A CSCL system could include one-to-one, one-to-many, or many-to-many synchronous or asynchronous text, image, audio, or video communications in its design. Cooperative learning on such a system would support more diverse and fertile activities. However, as the conventional classroom has to be restructured to allow cooperative learning (Graves & Graves, 1985), the computer supported virtual space must also be well established. According to the thoughts on restructuring the classroom by Graves and Graves, two kinds of space were suggested in CSCL systems. For group members to huddle together and interact closely, an intra-group space should be designed for each group. Within the intra-group space, the members of a group can meet, discuss, and cooperate. To discourage interference from nonmembers, the system should separate the intra-group spaces of different groups and hinder outsiders from intruding. This would
further facilitate the feeling of group identity. However, to support cooperation or competition among groups, the system should also provide an inter-group space. Using this inter-group space, groups can get together to cooperate or compete with one another.

**Cooperative Skills Instruction**

In addition to the previously listed components, if group members have the appropriate interpersonal and small-group skills, cooperative learning could be further improved (Johnson & Johnson, 1994). However, these skills are not inherent. They require direct instruction, practice, prompts and accumulated experience. Inspired by the thoughts of applying cooperative learning strategies in CAI activities (Brush, 1998; Hooper, 1992; Rysavy & Sales, 1991; Sherman & Klein, 1995), there are several designs suggested to be embedded in CSCL systems. The system could include an online tutorial to introduce proper skills and a fabricated situation for students to practice these skills prior to activities. Some memos or prompts could be designed and embedded in the systems for reminding student to use these skills during the activity. After the activity, the system could require students to reflect upon how they worked together as a team. Synchronous or asynchronous communication techniques could be used for the reflection action. Typical subjects for reflection, for example, could be: (a) how well they achieved their group goals; (b) how they used positive behaviors and attitudes to enable the entire group to be successful; and (c) what they need to do next time to make their groups more successful. Alternatively, the system could require students to respond to an online checklist concerning cooperative skills usage by the other members and/or themselves. In addition, because rewarding individual or group skill use would reinforce using the skills (Johnson & Johnson, 1990, 1991), the system could provide teachers methods to monitor and judge students. The behaviors of students in using a synchronous chatroom, and asynchronous e-mail or bulletin board, the results from a self-check or peer evaluation with checklists, as well as the teacher’s judgment could be traced and recorded. The recorded data could serve a righteous base for rewards.
SUMMARY AND SUGGESTIONS

This article redefined the essentials of cooperative learning, and converted them into the six components of CSCL systems to support a cooperative group structure, cooperative task structure, cooperative incentive structure, individual accountability structure, cooperative space structure, and cooperative skills instruction respectively. These components could constitute a framework for a CSCL system and serve as guidelines for CSCL system developers. Figure 2 illustrates an example system developed according to this framework. This system adopted a centralized architecture instead of a replicated architecture because of its simplicity at managing concurrency (Ahuja, Ensor, & Lucco, 1990; Greenberg, 1990; Patterson, Hill, Rohall, & Meeks, 1990). It is a web-based system so that a group of geographically dispersed students can collaborate and learn synchronously and asynchronously through a web browser.

While there have been a few studies that examined the academic and social impact of CSCL, which components (structures) are more or less important and effective could not be determined. Maybe not every one of these components must be used every time CSCL developers design a system. However, a system without these components would be rather like a general groupware than a CSCL system. Such a system would be applicable for mature people to cooperate, but would not be suitable for schoolchildren to cooperate and learn. Unless the assistance of a teacher, who is proficient in cooperative learning strategies and technology usage skills, using a general groupware, just as in a traditional classroom, opportunities for effective interaction and learning could not be guaranteed. In summary, the development of CSCL systems requires careful attention to the essentials of cooperative learning. To realize what elements or components are more vital, further research must be performed.
Figure 2. Architecture of a CSCL system
References


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