A Model and a Game for Investigating, Designing and Teaching Collaborative Learning

César A. Collazos[1]
Dept. Computer Science
Universidad de Chile
Av.Blanco Encalada 2120
56-2-6784890
ccollazo@dcc.uchile.cl

Luis A. Guerrero
Dept. Computer Science
Universidad de Chile
Av.Blanco Encalada 2120
56-2-6784890
luguerre@dcc.uchile.cl

José A. Pino
Dept. Computer Science
Universidad de Chile
Av.Blanco Encalada 2120
56-2-6784890
jpino@dcc.uchile.cl

Gerry Stahl
College of Information Science & Technology
Drexel University
Philadelphia, PA, USA
1-215-895-0544
gerry.stahl@drexel.edu

Sergio F. Ochoa
Dept. Computer Science
Universidad de Chile
Av.Blanco Encalada 2120
56-2-6784890
sochoa@dcc.uchile.cl

ABSTRACT

Collaborative learning in classrooms requires carefully crafted environments – both technical and social. This paper presents a model describing how to design socio-technical environments that will promote collaboration in group activities. A software tool was developed based on this model for use in conducting experiments in collaborative learning. Preliminary testing with this system revealed strengths and weaknesses of the system, which are being addressed in on-going research.

Categories and Subject Descriptors

H.5.3, H.5.2, H.5.

General Terms

Design, Experimentation, Human Factors.

Keywords

CSCL, Collaboration Models.

1. INTRODUCTION

Quantitative research in CSCL is difficult because it is hard to measure collaboration for a number of reasons:

- Effective collaborative learning depends on subtle social factors and pedagogical structuring, not just simple tasks and technologies [1].
- Collaborative learning technologies must go beyond generic groupware applications, and even the basic technology is not yet well developed [29].
- Settings of collaboration in classrooms and other groups are "messy" compared to classic laboratory research settings, full of intervening factors that cannot be controlled for [3].
- CSCL technology is complex, hard for users to learn and difficult to assess because it must be used by groups, not individuals [2].
- Interactions in experiments are unique, impossible to replicate in their details.
- Quantitative measures of collaborative interactions tend to lose the collaborative content [28].

Yet, the advantages of collaborative learning are well documented [4, 5, 6].

We are interested in systematically investigating the collaborative process using a traditional laboratory experimental approach and quantitative measures, as well as studying collaboration qualitatively "in the raw" in other work. In order to study

[1] On leave from FIET, Universidad del Cauca-Colombia

collaboration in a controlled setting, we have developed a software system that requires four subjects to collaborate with each other to play a certain game made up for this. In designing the software tool that controls the interactions among subjects, we developed a model that specifies initial conditions and the design of the structure of the shared workspace which structures the collaboration.

This paper presents our model for designing environments that explicitly promote collaboration (see section 2). Section 3 presents the software tool developed on the basis of the model. Section 4 briefly reviews initial data from a series of experiments using the software, and section 5 presents preliminary conclusions and future work motivated by the results.

We believe that diverse methodologies must be used in order to develop an adequate understanding of collaboration and collaborative learning. These methods may encompass both quantitative and qualitative analyses of interactions at multiple units of analysis. This paper is part of our larger effort, that includes, for example, studies using additional collaboration games based on the same model (MemoMet, ColorWay, TeamQuest) and a larger theoretical context including design patterns and collaborative scenarios [36] as well as qualitative interaction analyses of students using scientific simulations [37]. Here, we focus on presenting a game that is designed to provide students an experience of collaborative learning – an experience that can be quantified along key dimensions or "indexes of collaboration." Such a game provides a useful tool for conducting controlled experiments in collaborative learning. We provide a model that specifies the experiment's initial conditions and activity structure, allowing the researcher to control these variables and quantify an interesting set of indicators.

2. THE MODEL

Instead of designing systems that compensate for metacognitive deficiencies by becoming increasingly directive, we should develop systems that support the learner's metacognitive activities (or even better, that develop their metacognitive skills) [7]. Hewitt et al. state that a computer-supported learning environment can serve not only as an on-line conferencing facility but also as a true learning environment if it enables participants to represent a problem from multiple perspectives, to build knowledge communally, and to examine knowledge and refine design elements at different levels of abstraction [8].

As Dillenbourg mentions, in collaborative learning environments particular forms of interactions are needed to trigger the desired learning mechanisms [1]. There is, however, no guarantee that those interactions occur. Hence, the idea is to develop mechanisms for increasing the probability that they will happen. One of these ways is by designing well-specified collaborative scenarios. It is necessary therefore, to design the learning task and the learning environment. Dillenbourg offers an excellent account of collaboration in learning processes from a cognitive psychology perspective [1]. He is especially interested in problem-based tasks, and looks at both paired and group-based collaborations. He mentions that there is an indirect connection between a collaborative learning situation and its learning outcomes. There are important intervening variables: situations generate interaction patterns; interactions trigger cognitive mechanisms; mechanisms generate cognitive effects. What the learner does is important. We cannot influence this directly, but we can try to create *scenarios* which are conducive to promoting helpful interactions.

The design of the learning task needs to draw on the best of what we know about how people learn, on a deep knowledge of academic subject matter and/or vocational competencies, and on knowledge of the learners. A task needs to be sufficiently well-specified that the chances of a learner engaging in unproductive activity are kept within tolerable limits. The learning environment is the physical environment or physical settings within which learners work [27].

2.1 Set-up initial conditions

A first way to increase the probability that some types of interaction occur is to carefully design the situation. Numerous independent variables have been studied in order to determine the conditions under which collaborative learning is efficient. Based on the elements proposed by Bannon [9], our model defines a set of elements to consider in order to specify the initial characteristics of the groups.

2.1.1. Type of activity: Specify the type of activity that will be performed by the members of the group in order to solve a problematic situation. It could, for example, include tasks such as: puzzle solving, editing a newspaper, writing a letter, etc.

2.1.2. Nature of collaborators: Specify the types of interaction that occur. For example, it could include three types of interaction:

- Peer to peer interaction.
- Teacher-student interaction.
- Student-computer interaction.

2.1.3. Group heterogeneity: This covers several independent variables such as: size of the group, gender and differences of the group members.

The size specifies the number of participants within a collaborative activity. Generally speaking, the smaller the group, the more each member talks and the less chance there is that someone will be left out. Also, smaller groups requires less group management skill and can usually come to decisions faster [10]. Gender specifies the male/female group composition. Some studies have found the influence of this factor within a collaborative learning process [11].

2.1.4. Positive interdependence: This corresponds to one of the key elements in successful groups. Based on hundreds of studies, psychologists working in education identified positive interdependence as a characteristic of successful learning groups [12, 13].

Positive interdependence simply means that group members feel that they sink or swim together. In other words, what helps one group member helps them all, and what hurts one group member hurts everyone in the group. Johnson et. al. have defined nine types of positive interdependence : goal, role, outside enemy, resource, fantasy, identity, reward and environmental interdependence [12]. Collazos et al. have developed diverse forms of structuring positive interdependences in software tools based on the interface design to ensure that students think "we" instead of "me" [33].

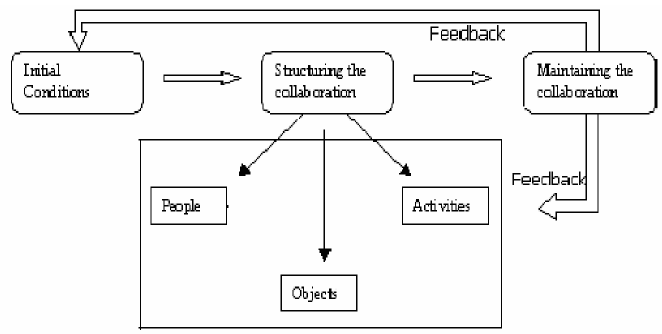

Figure 1: Model Proposed

2.1.5. Setting of collaboration: This corresponds to the place where the collaborative activity will be held. It could correspond to the classroom, workplace, home, etc.

2.1.6. Conditions of collaboration: This specifies the kind of mediation. It could be, physically co-present or computer-mediated.

2.1.7. Period of collaboration: This specifies the interval time in which the collaborative activity will occur. It could be specified in minutes, hours, days, weeks, months or years.

2.2. To structure the collaboration

The teacher cannot simply ask students to start projects and encourage peers to learn together, but should specify a scenario. That scenario should include several phases. At each phase, the team has to produce something and the team members have some role to play. The scenario we propose includes three characteristics: activities, people, and objects. As Jerman et al. mention, coaching collaborative interaction means supporting or managing the group members' metacognitive activities related to the interaction. For example, one might help students manage their interactions by assigning roles, detecting conflicts and misunderstandings, or proposing suitable tasks for each participant, given their level of expertise [25]. Our model looks at the following aspects of a scenario:

2.2.1 Activities : Specify the tasks that must be performed by the group members during the collaborative activity. This includes the goals and rules of the tasks.

2.2.1.1. Goals: There are activities performed by the group that correspond to the main goal, and activities performed by every member of the group that correspond to the partial goals.

One of the most commonly heard objections to having students work in groups is that some group members will end up doing all the work and all the learning. This can occur because some students try to avoid working or because others want to do everything [10]. Thus, encouraging everyone in the group to participate is a real concern. To do this we need everyone to feel that they are individually accountable for the success of the group.

2.2.1.2. Rules: Specify the rules of the group activity. These rules mediate the subject-community relationship, and refer to the explicit and implicit regulations, norms and conventions that constrain actions and interactions within the activity system [14]. These rules permit the review of boundaries and guidelines of the group activity, and according to Collazos et al., correspond to one of the indicators of a collaborative learning process [15].

2.2.2 People: Specify the roles of the group members during a collaborative activity. Each group member has a designated role which they are to perform. For example, a reading passage can be divided into sections. Members of a pair read the first section silently. Then, one person summarizes the section and the other makes connections between the section and other materials the class has studied. These roles can rotate.

Based on the collaborative learning scenario they established, Johnson & Johnson [16] suggest four types of roles: reader, expert, mediator and secretary. The *reader* is in charge of reading the problem and explaining it clearly to the group. The *expert* is in charge of constructing the solution to the question assigned to him and to inform the rest of the group about it. The *mediator* is in charge of aiding the even participation of all group members, as well as to control the time in the group. Finally, the *secretary* is the person that records all the solutions obtained by the group. These roles are not fixed, they should be rotated among the group members while the activity is in development, since interchanging roles is a very positive aspect in the collaborative learning activities [17].

2.2.3 Objects: Define the tools through people who can perform the collaborative activities. They must include aspects related with communication and participation.

2.2.3.1 Communication. Define mechanisms that support communication among members of the group, such as chat boxes, messages boxes, etc. Delvin and Rosemberg emphasized the importance of communication in individual knowledge and cooperative practices such as sign language with hands in face-to-face communication [18]. The participants of group work must communicate in order to accomplish tasks that are independent, that are not completely described or that require negotiation [19].

2.2.3.2 Participation. The idea is to define scenarios where members of the group have the same opportunities to participate in order to solve the problematic situation. The complexity of the activities must be designed in a way that every member of the group can perform the same work. It is important to notice that just because one person in the group is talking or performing any activity does not mean that each member of the group has the same amount of opportunity to talk and to intervene in order to solve the problematic situation. Kagan and Kagan have defined equal participation as one of the principles which are key to the structural approach to cooperative learning [20].

2.3 To maintain the collaboration

The last aspect we consider in our model is to design scenarios where it could be possible to maintain the collaboration among members of the group. That activity could be performed by the cognitive mediator or by the same members of the group.

Even if the efforts to structure collaboration increase the probability that productive interactions would occur, there is no guarantee that the interactions do actually occur. For that reason, it is necessary to have some external regulation in order to satisfy the occurrences of those kinds of interactions. One way to provide that kind of regulation is through the cognitive mediator.

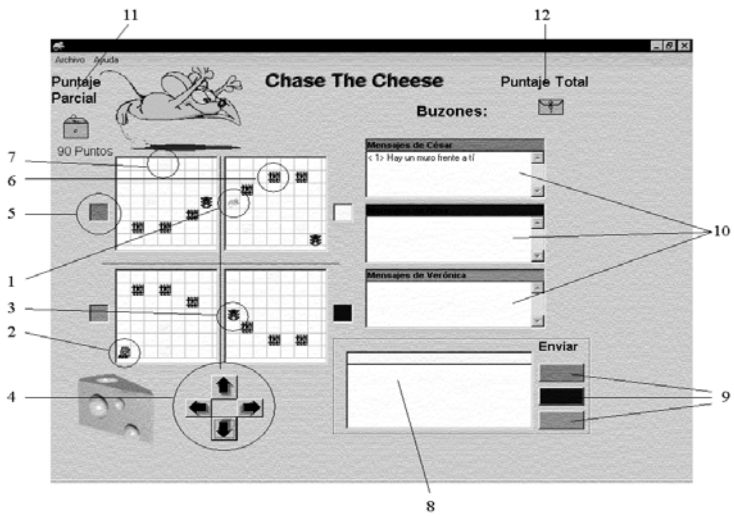

Figure 2: Game Interface

The role of cognitive mediator will not be to intervene at the task level, but to guarantee that all the group members participate, and to frequently ask questions such as: What happened? What does it mean? [21] The role of the cognitive mediator is to maintain the focus of the discussion, guiding students through the knowledge construction process. As the collaboration progresses, the state of interaction is evaluated and remedial actions may be proposed to reduce discrepancies between these states.

Figure 1 depicts the model we propose. This model attempts to support collaboration through two approaches: structuring the situation in which the collaboration takes place (set up initial conditions and structuring the collaboration), and, structuring the collaboration itself through coaching or self regulation (maintaining the collaboration).

Next we are going to explain a software tool we have developed based on the model proposed above.

3. SOFTWARE TOOL

A game – called *Chase the cheese* – is played by four persons, each with a computer. The computers are physically distant and the only communication allowed is computer-mediated. All activities made by participants are recorded for analysis and players are made aware of that. Players are given very few details about the game. The rest of the game rules must be discovered by the participants while playing. They also have to develop joint strategies to succeed. Therefore, people can only play the game once.

Figure 2 shows the game interface. To the left, there are four quadrants. The goal of the game is to move the mouse (1) to its cheese (2). Each quadrant has a *coordinator* –one of the players– permitted to move the mouse with the arrows (4); the other participants – *collaborators* – can only help the coordinator sending their messages which are seen at the right-hand side of the screen (10). Each player has two predefined roles: *coordinator* (only one per quadrant and randomly assigned) or *collaborator* (the three remaining). The game challenges the coordinator of a quadrant in which the mouse is located because there are *obstacles* to the mouse movements. Most of the obstacles are invisible to the quadrant coordinator, but visible to one of the other players. In each quadrant there are two types of obstacles through where the mouse cannot pass: general obstacles or grids (6) and colored obstacles (7). This is one of the features of the game which must be discovered by the players. The players must then develop a shared strategy to communicate obstacle locations to the coordinator of the current quadrant. No message broadcasting is allowed, so players have to choose one receiver for each message they send (9). Since each participant has a partial view of the labyrinth, she must interact with her peers to solve the problem. In order to communicate with them, each player has a dialogue box (8) from which she can send messages to each of them explicitly (one at a time) through a set of buttons associated to the color of the destination (9). For example, in Figure 2, she can send messages to the players with blue, red and green colors.

Since each player has a color associated to her, her quadrant shows the corresponding color (5). When starting to move the mouse, the coordinator has an individual score (11) of 100 points.

Whenever the mouse hits an obstacle, this score is decreased 10 points. The coordinator has to lead the mouse to the cheese (in the case of the last quadrant) or to a traffic light (3), where the mouse passes to another quadrant and her role is switched to collaborator and the coordinator role is then assigned to the next player (clockwise). When this event occurs, the individual score is added to the total score of the group (12). Both scores, partial and total are hidden; if a player wants to see them, she must pass the mouse over the corresponding icon displaying the score for two seconds. If any of the individual scores reaches a value below or equal to 0, the group loses the game. The goal of the game is to take the mouse to the cheese and do it with a high total score (the highest score is obviously 400 points).

Let's see how we design the software interface according to the model proposed in the previous section. Table 1 presents the initial conditions in the software tool we have developed (chase the cheese).

Table2, presents the way we structured the collaboration among members of the group in the software tool we have developed.

Table 1: Initial Conditions.

Elements	Chase the cheese
Type of activity	Solve a labyrinth
Nature of Collaborators	Peer to peer interaction
Group heterogeneity	The game is played by four person, randomly selected.
Positive Interdependence	Goal interdependence, because, there is a common goal, in that case, lead the mouse to its cheese
	Role interdependence: There are two predefined roles, coordinator and collaborators.
	Resource interdependence: Every member of the group has information that the other ones need. They have a partial view of the labyrinth, because they have information about their own colorful obstacles.
	Reward interdependence: Group members not only must lead the mouse to its cheese but arrive with the highest score.
Setting of Collaboration	Classroom
Conditions of Collaboration	Computer-mediated
Period of Collaboration	45 minutes

Table 2: Structuring collaboration

Elements	Chase the Cheese
Activities	Global: Lead the mouse to its cheese
	Partial: Pass through every traffic light icon
	Rules : The coordinator is the only person able to move the mouse. When the score arrives to 0, the game is over.
People (Roles)	Coordinator: one per quadrant
	Collaborators: the three remaining
Objects (Communication)	The system provides some dialogue boxes, where every participant can send messages to every member or the group. Also, includes mailbox messages, where each player can see the messages he/she has received from the other players.
Objects (Participation)	In order to guarantee equal participation of all members of the group, the labyrinth was designed with a similar complexity in every quadrant. Every quadrant was designed in a way that had the same number of obstacles (general and colorful), and their distribution was similar in all the quadrants.

The third part of the model, maintaining the collaboration, according to the model proposed includes the participation of the cognitive mediator. Our experience with the software tool did not include that part in an explicit way. We only presented the information at the end of the activity. Through a semantic analysis of the messages, it was possible to re-build the collaboration processes, and so, to determine the degree of collaboration according to our proposed indicators [15]. In future versions, we will show some visualization of the interactions among the members of the group. Then, the participation of the cognitive mediator could be important. The cognitive mediator and/or participants could interpret the visualization and decide what actions (if any) to take, in order to improve the collaboration[35]. It could be possible, that students who view and analyze our proposed indicators values [15], may learn to understand and improve their own interaction.

Next, we are going to present some initial experiments we have developed.

4. EXPERIMENTS

This experiment consists of 11 groups of four students carrying out the software tool explained before. The groups that participated in the initial experiment were the following:

- A group of graduate students from the "Collaborative Systems" course at a university, with some experience on collaborative work techniques (group 0).
- Randomly selected people who have not met before and have never worked together (group 3).
- Friends who have worked as a group many times before this experiment and have a good personal relationship (group 4).
- Four groups of high school students. These students were 15 years old on the average. Two of these groups were randomly selected (group 1 and 2) and the remaining ones included friends (group 5 and 6).
- Four groups of graduate students, from a second university (Groups 7, 8, 9, 10).

In order to measure the results, they were analyzed taking into account two indicators defined by Collazos, et al. [15], whose main objective is to evaluate the collaborative learning process. These Indicators (or Indexes) of Collaboration (CI) are based on the activities proposed by Johnson & Johnson in [22]: applying strategies (IC1), intra-group collaboration (IC2), success criteria review (IC3), monitoring (IC4) and performance (IC5). The first indicator tries to capture the ability of the group members to generate, communicate and consistently apply a strategy to jointly solve the problem [34].

4.1 Applying strategies (IC1)

Group members are forced to closely interact with peers since each player has a partial view of the game obstacles. Therefore, the game presents a strict positive interdependence of goals. If the group is able to solve the game, we can say their members have built a shared understanding of the problem. They must have understood the underlying problem: the coordinator does not have all the information needed to move the mouse in her quadrant without hitting any obstacle, so she needs the timely assistance from her collaborators. According to Fussell [19], the discussion of the strategy to solve the problem helps the group members to construct a shared view or mental model of their goals and tasks required to be executed. This mental model can improve the coordination, because each member knows how her task fits into the global team goals.

The learning potential of a team is maximized when all the students actively participate in the group discussions. Building involvement in group discussions increases the amount of information available to the group, enhancing group decision making and improving the students' quality of thought during the learning process [30].

In general, the specific measures to be considered for this indicator are subject-related. In our case study (Chase the Cheese), we estimated both the strategy the group applied and its success should be part of the indicator. Furthermore, we thought the strategy should have a weight four times larger than the one assigned to the success factor (whether or not the group solved the labyrinth). Thus, the first indicator (CI1) should be built with 80% weight for the applied strategy and 20% weight for the success factor.

The strategy factor mentioned above was built from simple measures which could be obtained from the raw data. The 80% weight was explained as 20% for whether or not the group was able to outline a strategy for the problem solution in an explicit way, 25% for use of the defined strategy, 30% to negotiate, reach consensus and disseminate information about strategy, and 5% for the quality of the strategy. The quality measures included number of errors made by the group (related to the score) and number of mouse movements (related to efficiency).

4.2 Intra-group cooperation (IC2)

This indicator corresponds to the employment of collaborative strategies previously defined during the process of group work. If each group member is able to understand how her task is related to the global team goals, then every one can anticipate her actions, requiring less coordination efforts. This indicator also includes measures related to the requirements of every player from her peers to reach her partial goal when acting as a coordinator.

A group achieves promotive interdependence when the members of the group perceive that their goals are positively correlated such that an individual can only attain her goal if her team members also attain their goals [31]. In collaborative learning, these goals correspond to each member's need to understand her team members' ideas, questions, explanations, and problem solutions.

We have defined the CI2 indicator as: 80% employment of collaborative strategies and 20% providing help. Measuring the employment of collaborative strategies implies the evaluation of coordination procedures and assessing the degree of joint understanding of the strategy. A good employment of collaborative strategies should be observed as an efficient and fluid communication among members of the group. Good communication, in turn, means few, precise and timely messages (1 – (work strategy messages)/(work messages)). Providing help may be measured by the supporting messages from peers when the coordinator requests them.

4.3. Success criteria review (IC3)

This indicator measures the degree of involvement of the group members in reviewing boundaries, guidelines and roles during the group activity. It may include summarizing the outcome of the last task, assigning action items to members of the group, and noting times for expected completion of assignments. The beginning and ending of any group collaboration involve transition tasks such as assigning role, requesting changes to an agenda, and locating missing meeting participants.

In the game, the success or failure of the group is related to the partial and global goals. It is shown in the obtained scores (partial and global scores). This indicator also should take into account the number of messages concerned with the reviewing mentioned above. It reflects interest in individual and collective performance. In our experiment, the more concerned the player is with the goals of the team, the more checks to the scores she will do, and the more messages of this kind she will send. CI3 is then computed with a 0-1 range, where 1 means the highest score in this indicator.

4.4. Monitoring (IC4)

This indicator is understood as a regulatory activity. The objective of this indicator is to oversee if the group maintains the chosen strategies to solve the problem, keeping focussed on the goals and the success criteria. If a player does not sustain the expected behavior, the group will not reach the common goal. In this sense, our fourth cooperation indicator (CI4) will be related to the number of coordination messages, where a small number of messages means good coordination (1 – (Coordination strategy messages)/(Coordination messages)).

4.5. Performance (IC5)

This refers to the quality of the proposed solution to the problematic situation. Baeza-Yates and Pino [32] made a proposal for the formal evaluation of collaborative work. They take into account three aspects: Quality (how good is the result of collaborative work), Time (total elapsed time while working) and Work (total amount of work done). So, in our experiment, Quality can be measured by three factors: few errors made by the group (related to the best score), achievement of the main goal (the group can solve the labyrinth) and few movements of the mouse (related to efficiency). The tool records the play-time since the first event (movement of the mouse or message sent by any player), until the group reaches the goal (cheese) or loses the game (a partial score goes down to zero). In this view, the "best" group does the work faster. Work is measured by the number of messages sent by group members. The performance indicator (CI5), will be the average of the three aspects mentioned above (Quality, Work, Time).

4.6 Results

Table 3 presents the results in each indicator.

Table 3: Results

	IC1	IC2	IC3	IC4	IC5
Group 1	0.69	0.69	0.2	0.75	0.65
Group 2	0.31	0.71	0.2	0.80	0.57

Group 3	0.68	0.62	0.2	0.80	0.69
Group 4	0.48	0.61	0.5	0.74	0.63
Group 5	0.71	0.74	0.8	0.78	0.66
Group 6	0.75	0.84	1	0.86	0.61
Group 7	0.71	0.72	1	0.85	0.52
Group 8	0.47	0.80	0.2	0.80	0.53
Group 9	0.27	0.75	0.2	0.82	0.54
Group 10	0.28	0.75	0.2	0.81	0.54
Group 11	0.48	0.80	0.2	0.83	0.53

Although some groups got a good score in some indicators, making a detailed analysis, we can see that almost all the groups studied were ineffective collaborative groups because they were weak in collaborative attitudes (for detailed analysis, see [15]). Students have two responsibilities in cooperative learning situations, according to Johnson & Johnson: 1) learn the assigned material, and 2) ensure that all members of the group learn the assigned material [23]. The second aspect is something that never occurred during the collaborative learning processes of our groups. Of course, nobody told the group members they should have a collaborative attitude. Many hypothesis can be developed to explain why these attitudes did not appear spontaneously: perhaps the students initially thought the game was very easy, or maybe they felt pressured to play instead of stopping to think carefully what to do, etc.

4.7 Discussion

In spite of the fact that our application includes many of the elements proposed in our model, the results obtained were not the best. What matters is not just the design of a computer tool or program, nor even the design of a single task or curricular unit. Rather, the cultivation of minds, which itself requires mindful engagement in a social process of meaning appropriation, requires that the whole environment, not just the computer program or tool, be designed as a well orchestrated whole. This includes curriculum, teacher's behavior, collaborative tasks, mode of peer collaboration and interaction, tasks, learning goals, and the like. Kozma has found, in an analysis of student interaction, that the amount and nature of collaboration between partners had less to do with the availability of computer software and more to do with the way the instructor designed and structured the task [26].

5. CONCLUSIONS AND FUTURE WORK

The design of well-specified scenarios could induce collaborative activities within a group. So, it is important to carefully define every activity, in order to promote collaborative activities. We have proposed a model that includes a set of elements to be performed to specify scenarios that promote collaborative activities.

Based on our results, we believe it is not only important to design the software tool and the task, but to consider other aspects such as teacher's participation, learning goals, etc., in order to have a collaborative environment. The model we present attempts to support collaboration through two approaches: structuring the situation in which the collaboration takes place (set up initial conditions and structuring the collaboration), and, structuring the collaboration itself through coaching or self regulation (maintaining the collaboration). In future versions, we will build software tools that monitor the state of the interaction, model the state of the interaction and provide collaborators with visualizations that can be used to self-diagnose the interaction.

ACKNOWLEDGMENTS

This work was supported by Fondecyt (Chile) grants Nº 1000870 / 1030959, and graduate thesis scholarship No.49 from Departamento de Postgrado y Postitulos, Universidad de Chile (2002).

REFERENCES

[1] Dillenbourg, P., What do you mean by collaborative learning?. In P. Dillenbourg (Ed) *Collaborative-Learning: Cognitive and Computational Approaches*. Pp. 1-19, Oxford: Elsevier, 1999.

[2] Muhlenbrock, M., Hoppe, H., Constructive and collaborative learning environments: What functions are left for user modeling and intelligent support? In B. Bredeweg (Ed.), *ECAI-98*, pp.25-29, Brighton, England, 1998.

[3] Leont'ev, N., The problem of activity in psychology. In J.V. Werstsch (Ed.) *The concept of activity in Soviet psychology*. Armonk, NY: Sharpe, 1981.

[4] Johnson, D.W. Stanne, M.. A comparison of computer-assisted cooperative, competitive, and individualistic learning. *American Educational Research Journal 23,* 382-92, 1986.

[5] Cooperative learning and sociocultural factors in schooling. In California Department of Education (Ed), *Beyond language: Social and cultural factors in schooling language minority students*. Los Angeles, CA: Evaluation, Dissemination and Assessment Center, California State University, Los Angeles, 1986.

[6] Slavin, R., Cooperative learning and student achievement. In R.E. Slavin (Ed), *School and classroom organization*. Hillsdale, NJ: Erlbaum., 1988.

[7] Dillenbourg, P, The computer as a constructorium: Tools for observing one's own learning. In M.Elsom-Cook and R.Moyse (Eds), *Knowledge Negotiation*, pp.185-198, London Academic Press, 1992.

[8] Hewitt, J., Scardamalia, M., Webb, J., Situative design issues for interactive learning environments: The problem of group coherence. *AERA'97*, Chicago, 1997.

[9] Bannon, L., Issues in computer-supported collaborative learning, NATO Advanced workshop on computer-supported collaborative learning, Italy, sept. 1989.

[10] Kagan, S., Cooperative learning. San Jaun Capistrano, CA: Kagan Cooperative Learning, 1992.

[11] Collazos, C., Guerrero, L., Llaña, M., Oetzel, J., Gender: an influential factor in the collaborative work process. *ICNEE*, pp. 7-11, Lugano, Switzerland, 2002.

[12] Johnson, D., Johnson, R., Holubec, E. Circles of learning (4^{th} edition). Edina, MN: Interaction Book Company, 1993.

[13] Slavin, R., Cooperative learning: Theory, research and practice. Englewood Cliffs, NJ: Prentice-Hall, 1990.

[14] Engestrom, Y., Learning by expanding: an activity-theoretical approach to development research. Orienta-Konsultit Oy, Helsinki, 1987.

[15] Collazos, C, Guerrero, L., Pino, J., Ochoa, S. (2002) Evaluating collaborative learning processes. In J. Haake & J. Pino (Eds.) *Groupware: Design, Implementation and Use*, Springer Verlag, Berlin, Germany, pp. 203-221.

[16] Johnson D., Johnson R, Holubec, E.: *Cooperation in the classroom*. Interaction Book Company, Edina, MN, 1998.

[17] Dillenbourg, P., Baker, M., Blake, A. y O'Malley, C.: The Evolution of Research on Collaborative Learning (Spada, H. and Reimann, P. Eds.), *Learning in Humans and Machines: Towards an Interdisciplinary Learning Science*, pp-189-211, Oxford, Elsevier, 1995.

[18] Delvin, K., Rosemberg, D. Language at work: analyzing communication breakdown to inform system design. *CSLI lecture notes* no.66, 1996.

[19] Fussell, S., Coordination, overload and team performance: effects of team communication strategies. *CSCW'98*, Chapel hill NC, pp.275-284, 1998.

[20] Kagan, S., Kagan, M., The structural approach: six keys to cooperative learning. *Handbook of cooperative learning methods*, ed. By S. Sharon, pp. 115-133. Westport, CT: Greenwood Press, 1994.

[21] Collazos, C., Guerrero, L., Vergara, A., Aprendizaje Colaborativo: un cambio en el rol del profesor. *Jornadas chilenas de la Computación. III Encuentro de Educación en la computación*, Punta Arenas-Chile, 2001.

[22] Adams, D., Hamm, M. Cooperative learning, critical thinking and collaboration Across The Curriculum. Second Edition, 1996

[23] Johnson, D., Johnson, R.: Cooperative, competitive, and individualistic learning. *Journal of Research and Development in Education*, Vol. 12,p.p. 8 –15, 1978.

[24] Newman, D. Sixth graders and shared data: designing a LAN environment to support collaborative work. *CSCW'98*, pp.291-305, Portland, 1988.

[25] Jerman, P., Soller, A., & Muehlenbrock, M., From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *Proceedings of Euro-CSCL1*, March 2001, Maastricht.

[26] Kozma, R., Students collaborating with computer models and physical experiments. *Proceedings of CSCL'99*, pp. 314-322, Stanford, 1999.

[27] Steeples, C., Jones, C, Goodyear, P. Beyond E-Learning: A future for networked learning. In *Networked Learning: Perspectives and Issues* (Steeples and Jones, Eds.), pp.322-347, 2002.

[28] Stahl, G. (2002) Rediscovering CSCL. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL2: Carrying Forward the Conversation,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 169-181.

[29] Stahl, G. (2002) Groupware Goes to School. In J. Haake & J. Pino (Eds.) *Groupware: Design, Implementation and Use*, Springer Verlag, Berlin, Germany, pp. 1-24.

[30] Jarboe, S.: Procedures for enhancing group decision making. In B. Hirokawa and M. Poole (Eds.), Communication and Group Decision Making, pp. 345-383, Thousand Oaks, CA:Sage Publications, 1996

[31] Deutsch, M.: Cooperation and trust: Some theoretical notes. In M. Jones (Ed.) Nebraska Symposium on Motivation (pp.275-320). Lincoln: University of Nebraska Press, 1962.

[32] Baeza-Yates, R. and Pino, J. A.: A First Step to Formally Evaluate Collaborative Work. Int. Conf. GROUP '97, Phoenix, AZ, USA, pp. 55-60, Nov. 1997

[33] Collazos, C., Guerrero, L, Pino, J, And Ochoa, S., Collaborative Scenarios to promote positive interdependence among group members. In Favela and Decouchant (Eds.): Groupware: Design, Implementation and Use. Lecture Notes in Computer Science 2806, pp.356-370, 2003.

[34] Collazos, C., Guerrero, L., Pino, J., and Ochoa S., Evaluating Collaborative Learning Processes. In J. Haake and J.A.Pino(Eds.): Groupware: Design , implementation and Use. Lecture Notes in Computer Science 2440, 2002, pp.203-221.

[35] Collazos, C., Guerrero, L, Pino, J, And Ochoa, S., Improving the use of strategies in Computer-Supported Collaborative Processes. In Favela and Decouchant (Eds.): Groupware: Design, Implementation and Use. Lecture Notes in Computer Science 2806, pp.247-260, 2003.

[36] Collazos, C. (in preparation) A Methodology for the Computational Support of Evaluation and Monitoring in Collaborative Learning Environments. Unpublished doctoral dissertation, Department of Computer Science, Universtiy of Chile. Santiago, Chile.

[37] Stahl, G. (2002). *The complexity of a collaborative interaction.* Poster presented at the International Conference of the Learning Sciences (ICLS '02), Seattle, WA. Full paper available at http://www.cis.drexel.edu/faculty/gerry/cscl/papers/ch02.pdf