Evaluating Cooperation in Group Work

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Abstract

Several researchers in the area of cooperative work take as a success criterion the quality of the group outcome. Nevertheless, recent findings are giving more importance to the quality of "cooperation process" itself. This paper presents the design of a software tool that allow us to capture information concerned with the group work. Besides to reveal the final quality of the group outcome, this information permit us to verify the presence of a cooperation indicators, which in turn allow us to determine the quality of the work process. A conducted experiment is described, and the obtained data is discussed, comparing the quality of the collaboration process with the quality of the results obtained by the groups.

Keywords: cooperative process evaluation, cooperation indicators, cooperation quality.

1. Introduction

Several researches, both in the area of education and computer science, give different meaning to the terms *cooperation* and *collaboration*. Thus, terms such as *cooperative learning*, *collaborative learning* and even *group learning* are considered similar concepts in some studies, and different concepts in others. The same happens with the terms *cooperative work*, *collaborative work* and *group work*. This fact, perhaps, is due to the approach change that research in the area has undergone with time.

Dillenbourg *et al* maintain that during many years, theories of collaborative learning have been focused on how individuals work in group, and recently, they have focused on the group by itself, trying to establish when and under what circumstances collaborative learning is more effective than individual learning [6]. In this context, some independent variables have been identified and widely studied: the size and composition of the group, the nature and the objectives of the task, the media and communication channels, the interaction between peers, the reward system and sex differences, among others [1], [6], [13], [14]. Recent research is setting more emphasis on the study of collaboration *processes* and their support [4], [5].

Traditionally, the evaluation of collaborative learning has been made by means of examinations or tests to the students to determine *how much they have learned*. That is to say, we do a quantitative evaluation of the *quality of the outcome*. Some techniques of cooperative learning use this strategy (e.g. "Student Team Learning" [12], "Group Investigation" [11], "Structural Approach" [10] and "Learning Together" [8]). Nevertheless, little investigation has been done to evaluate *the quality of the collaboration process*.

Some authors settle a difference between *collaboration* and *cooperation* according to where the emphasis has been put: this can be in the process or in the final result. In this paper, we do not make differences between the terms *cooperation* and *collaboration*. We are focused on the comparison of the *quality of the collaboration process* against the *quality of the group outcome*.

Taking into account characterization of cooperative learning presented by Johnson & Johnson, we propose a set of indicators and an experiment with a tool instrumented to gather information that permit us to measure the quality of cooperation process. Also, we do not introduce a conversation protocol, so the communication occurring in the task is spontaneous, requiring semantic analysis.

In section 2, we present the Johnson & Johnson characterization of collaborative learning process. Next, we divide it into three phases according to the nature of the task. In section 3, we propose an evaluation instrument. In section 4 we describe the cooperation indicators as well as a method that permit us to evaluate some key points identified in the phases of collaborative learning. Section 5 describes the experiment design. In section 6 we analyze the obtained results, and in section 7 we compare the collaboration process versus the group outcome. Finally, section 8 presents some conclusions and proposals for future work.

2. Stages of cooperative learning process

A *cooperative learning process* is typically composed of several tasks that must be developed by the cognitive mediator or facilitator, and by the group of apprentices, defining naturally two categories of tasks.

In order to evaluate the cooperative learning process, we divide it into three phases according to its temporal execution: *pre-process*, *in-process* and *post-process*. Thus, *pre-process* tasks are mainly coordination and strategy definition activities and *post-process* tasks are mainly work evaluation activities. Both phases, pre-process and post-process, will be accomplished entirely by the facilitator. The tasks concerning to the *in-process* phase will be performed, to a large extent, by the group members. It is here where the interactions of *cooperative work process* takes place, so that, our interest concentrates in the evaluation of this stage. In order to specify this division, we present the structure of a cooperative learning activity proposed by Johnson & Johnson in [1], and next we classify each activity according to the stage we have identified[1]:

[1] Johnson & Johnson do not make this phase differentiation.

1. Design the content and main tasks objectives to be accomplished by cooperative groups (pre-process).
2. Specify the size of the groups. It is suggested to be up to 6 people depending on the nature of the task and the time available (pre-process).
3. Arrange the groups. Designate the students to conform each group or allow them to form the groups by their own (pre-process).
4. Arrange the room for the cooperative learning activity. The facilitator must be "attainable" by every group and their members can seat together with out interrupt other groups (pre-process).
5. Distribute the instructional material. This can be achieved of several forms (pre-process).
6. Design roles, such as: speaker, facilitator, recorder, executor, and observer (pre-process).
7. Specify the task directives: define the game rules (pre-process).
8. Apply strategies like positive interdependence of the goal, motivation of the peers and support to learning. Create a product related to a goal system where rewards are based on individual and group results (it is defined in the pre-process, but evaluated in the in-process phase).
9. Organize the intra-group cooperation, that is to say, define the collaboration strategies that are going to be used by the members of the group (pre-process, the definition of cooperation strategies occurs in the in-process phase).
10. Test the success criteria explaining the guidelines, limits and roles (pre-process, in-process and post-process phases). The success criteria must be defined at the beginning of the activity, and must be reviewed during the activity to check if the common goal is being reached, and after the activity, to check if the common goal was reached.
11. Determine the desired behavior (pre-process, definition of desired behavior occurs in the in-process phase).
12. Monitor the students, for example, verify that the previous point is fulfilled (phase of in-process).
13. Provide assistance when someone asks for it (in-process phase): it is provided to the whole group by the facilitator or peers.
14. Intervene when groups have problems to collaborate (in-process phase).
15. Terminate an activity (post-process phase).
16. Evaluate the quality of learning accomplished by the students (post-process phase).
17. Encourage students to perform an evaluation on how well does the group work altogether (at the end of the in-process phase).
18. Provide and foster feedback. Discuss how the activities could be improved (at the end of in-process phase).

Table 1. Activities of a cooperative learning process.

Pre-process	In-process	Post-process
Design the contents	Application of strategies (positive interdependence of the goal, motivation between pairs, aid to learn)	Inspect success criteria
Specify the group sizes	Intra-group cooperation	Present the activity closure
Arrange the groups	Probe the success criteria	Evaluate the quality of learning
Arrange the room	Monitoring	
Distribute the material	Provide help (from facilitator and from peers)	
Design the roles	Intervention in case of problems	
Specify the game rules	Account of the group	
Define the success criteria	Feedback	
Determine the desired behavior		

Table 1 summarizes the activities and specifies the corresponding phases. These activities define the structure of any cooperative learning activity that takes place in small groups, and in synchronous learning scenarios (face to face, same time, same place). We are interested in the evaluation of the activities that correspond to the *in-process* phase. Based on these, we will define some collaboration indicators.

The following section presents a software tool used as an instrument to evaluate the presence or absence of our indicators of collaboration. In section 4 we define these indicators.

3. Chase the Cheese

"Chase the Cheese" is a group game, implemented in a software tool that allows us to capture group information that occurs within a cooperative work interaction. In this section we describe the functionality of the system and the nature of the information registered when a group uses the tool.

3.1. System's functionality

The game is a labyrinth divided into four quadrants. Figure 1 shows the game interface. To win the game, the group (four players) must lead the mouse (1) to its cheese (2). It is the common goal, and to achieve it, every group member must fulfill a partial goal that is accomplished when every one of them "solve" their own quadrant. That is to say, the mouse is driven to a traffic-light icon (3) allowing the group to advance to the next quadrant. This is a decision making problem game.

Each player has two predefined roles: *coordinator* (only one per quadrant and randomly assigned) or *collaborator* (the three remaining). Also, each player is identified by a color, and the colored square besides the quadrant indicates who is the coordinator (5).

A coordinator must take decisions concerned to the movement of the mouse. The collaborators must support the coordinator to ensure that her decisions are accurate. When a coordinator leads the mouse to the traffic-light icon of her quadrant (or the cheese in the last one), her role is switched to collaborator and the coordinator role then, is assigned to the next player (clockwise).

The arrows to drive the mouse (4) are only enabled when the user is performing the role of coordinator. In each quadrant there are two types of obstacles through where the mouse cannot pass: general obstacles or grids (6) and colored obstacles (7). Though grids can be seen by every player, colored obstacles can only be seen by the player who has that assigned color. As an example, Figure 1 corresponds to the interface of the player assigned with the yellow color. For that reason, only the general grids (6) and the yellow obstacles can be seen (7) in her interface.

Since each participant has a partial view of the labyrinth, he or she must interact with their peers to solve the problem. In order to communicate with them, each player has a dialogue box (8) from which she can send messages for each of them explicitly (once at a time) through a set of buttons associated to the color of the destiny (9). For example, in Figure 1, he or she can send messages to the players with colors blue, red and green. Also, each player can only see the messages that the other players send to him or her in their mailbox messages (10), one for each player. Every mailbox has a title that displays the name of the player, as well as its color.

At the beginning of each quadrant, the coordinator has a partial score (11) of 100. Whenever the mouse

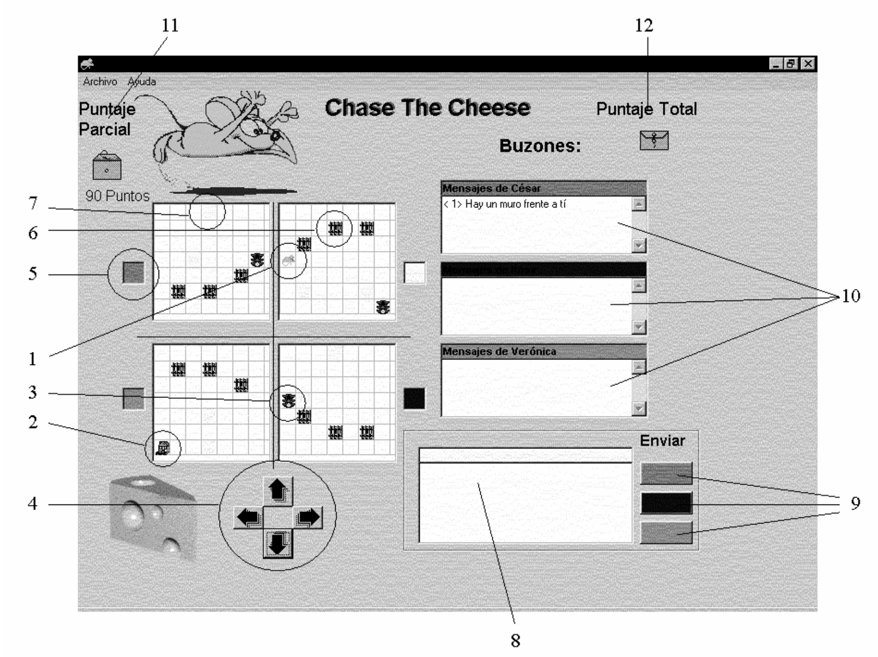

Figure 1: "Chase the Cheese" game interface.

hits an obstacle, her partial score decreases by 10 units.

When the coordinator reaches the traffic-light icon of her quadrant (the cheese in the last quadrant), the partial score is added to the total score of the group (12). The objective is not just to reach the cheese, but to arrive with the highest score (the maximum would be 400). If some partial score goes down to zero, the group loses the game. Both scores, partial and total, are hidden, if a player wants to see them, he or she must pass the mouse over their icon (11 or 12), unfolding the score by two seconds.

3.2. Information gathered

The application records every message sent by any member of the group. Along with each message, it registers the time of occurrence, sender, addressee and current quadrant (the mouse location when the message was sent). In addition, it records the partial scores and total score by quadrant. The tool also registers the start and finish time of the game, the time spent in each quadrant, and the number of times that each player looks at the partial and total scores by quadrant.

4. The indicators

Based on the structure of a cooperative learning activity explained above in section 2 (in-process phase), we define five indicators in order to evaluate the *cooperation degree* in the group interaction. These indicators are based on the following activities: use of strategies, intra-group cooperation, checking the success criteria, monitoring and the ability of providing help. So that, we defined four categories of messages: *coordination*, *work*, *strategy* and *lateral* messages. Subsequently, we established the *Index of Cooperation* (IC) as the average of these five indicators. This index allows us to evaluate the work process of the groups. In order to determine the values of our indicators, it is necessary to make semantic analysis of the messages.

In the first category, "coordination", we recognize those messages that correspond to activities which its main purpose is to regulate the dynamics of the process, and are characterized by prescribed future actions, such as "I will move six to the right". In the "work" messages category, we include those messages that help the coordinator to make the most suitable decisions. Those are sentences in present tense and have the aim to inform the group about the current state of the group task. In the experiment, it is referred to the state of the quadrant and the game. For example: "Stop, there is an obstacle in B3".

We identify as "strategy" messages all those that propose guidelines to reach the group goal, for example: "Let's label the columns with letters and the rows with numbers". Finally, the "lateral" message category includes the kind of particular messages (i.e. social messages, comments) and conversations that are not focused on the solution of the problem, for example: "Come on, hurry up, I'm hungry!!!!!!! ".

Next, we define the five indicators, along with the mechanism provided by the game to determine its presence or absence during the group interaction.

4.1. Applying strategies

Because each player has a partial view of the game obstacles, to solve the problem they have to interact closely with their group peers. Due to this necessity, the game presents a strict positive interdependence of goals. If the group is able to solve the game, we can say that their members have built a shared understanding of the problem (see Dillembourg definition of *collaboration* [6]). 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 opportune assistance from each collaborator. According to Fussell [7], 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 execute, this mental model can improve the coordination, because each member knows how their task fits into the global team goals. In this context, due to its high degree of inter-dependence, it's enough to consider the success or failure in solving the labyrinth to know if the group has applied strategies. This will be our first cooperation indicator (CI1). CI1 has a discrete value: 1 if they can solve the labyrinth (global goal) and 0 if they cannot.

4.2. Intra-group cooperation

This activity corresponds to the application of collaborative strategies during the process of group work. If each group member is able to understand how her task is related with the global team goals, then every one can anticipate their actions, requiring less coordination efforts. Because of this, our second cooperation indicator (CI2) is related to the "work" messages category: a good coordination procedure and a shared strategy, should be reflected in an efficient and fluid communication were the messages are precise, accurate and opportune, thus requiring fewer messages. To determine CI2, we consider a scale from 0 to 1, were 1 means fewest work messages sent between the group members.

4.3. Success criteria review

In the game, the success or failure of the group, related to the partial and global goals, is shown in the scores obtained (partial and global scores). The third cooperation indicator (CI3) reflects the interest in the individual and collective performance. The more concerned the player is with the goals of the team, the most queries to the scores she will do. CI3 is defined through a range from 0 to 1 where 1 means a high number of score queries.

4.4. Monitoring

The monitoring is understood as a regulatory activity. The objective of this activity is to oversee that the group maintain the chosen strategies to solve the problem, keeping focussed on the goals and the success criteria. If a player do 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 few amount of messages means a best coordination. It is expresed in a range from 0 to 1 where 1 indicates a better coordination.

4.5. Providing help

This activity is our fifth cooperation indicator (CI5), and is based on the ratio between the number of work messages and the total amount of messages spawned by the group. Each player requires help from their peers to reach her partial goal when acting as a coordinator, the ratio represents the involvement and concern degree of players in their role of colaborator (coordinator assistant). CI5 has a range from 0 to 1, where 0 means less interest and help (few information provided to the coordinator regarding the status of quadrant) and 1, a high degree of commitment to provide enough help.

The activity "*intervention in case of problems",* is not considered because we don't have a facilitator, except at the beginning of the game to explain the rules, so the help request through questions regarding how to play is not registered by the instrument).

At the end of the game a dialog window is presented to the players with the question: "What do you think of this experience?" An analysis of these answers would indicate if the group is able to self-evaluation, if they are able to understand the game, that is to say, to construct a shared understanding of the problem. However, due to its subjective nature, the *self-evaluation* and *feedback* activities are not evaluated in this experience.

5. Experimental design

The experiment has four phases. In the first phase the group receives a brief description of the software tool, in the second phase, group members are assigned to network workstations, in separate rooms (synchronous distributed interaction). From now on, all the communication is mediated by computer. During the third phase the group will try to solve the labyrinth. Finally, the fourth phase corresponds to the gather and analysis of data recorded in the tool logs. We made also a final interview to the participants to foster a self-evaluation of the experience, this will give us a general overview of the problem perceived by each member of the team. By the time, we have applied the experiment to seven groups, as we describe:

- A group of post-graduated students, from the course "Collaborative Systems" at the Pontificia Universidad Católica de Chile, with some experience on collaborative work techniques (group 0).
- A group of people, randomly selected, wich have not been meet among them and, of course, they never have worked as a group before (group 3).
- A group of friends that has worked in group many times before the experience and has a good personal relationship (group 4).
- Four groups of high school students from Cumbres de Santiago with an average age of 15 years old. Two of these were randomly selected (group 1 and 2) and the remaining ones were friends (group 5 and 6).

6. Results analysis

We define the *Index of Cooperation* (IC) as the average result of the previous identified indicators: IC = [CI1 + CI2 + CI3 + CI4 + CI5] / 5).

This section present a quantitative analysis of the data recorded, corresponding to the group wich has obtained the best IC (group 6) and the group with the worst one (group 3). We present, also, a preliminar interpretation of these results. Table 2 shows the results obtained by the groups.

6.1. Coordination messages

Figure 2 compares the results obtained by groups 6 and 3 in the *coordination messages category* throughout the four quadrants. It is important to notice that the curve corresponding to the number of this sort of messages of group 6 (best coordinated according to IC), keeps a flatten curve throughout the game., wich differs from group 3. In this case, the number of coordination messages decreases throughout the game, not allowing them to end the game (common goal).

6.2. Work messages

Work messages of both groups, 6 and 3, are shown in Figure 3. The curves pattern is similar to that of Figure 2. It suggest that there is a close relationship among those categories, where coordination activities regulate the tasks, but require a feedback from the players.

6.3. Strategy messages

Figure 4 shows the tendency of strategy messages curves for both groups, 6 and 3. As in the previous charts, the curve corresponding to group 6, presents a high degree of regularity, but a decreasing tendency in the group that was not able to solve the problem (group 3).

6.4. Lateral messages

Figure 5 presents the results obtained in the lateral or sided messages category for gopus 3 and 6. Notice the similarity of both curves, as in the tendency as well as in the total amount of messages sent throughout the four quadrants. This suggest that both groups develops, in a simmilar degree, a social and casual interaction behavior, but this does not influence significantly the performance obtained by the group, that is to say , a greater amount of messages does not imply a high degree of contribution and commitment to reach the common goal.

7. Process versus outcomes

Baeza-Yates and Pino [3] made a proposal for the formal evaluation of collaborative work. They take in to account three aspects: Quality (how good is the result of collaborative work), Time (total time elapsed while working) and Work (total amount of work done).

So that, in regard to our experiment, Quality can be

Table 2. Results of the Cooperation Indicators

Group	CI1	CI2	CI3	CI4	CI5	IC
0	1.00	0.80	0.20	1.00	1.00	**0.80**
1	0.00	0.40	0.20	0.60	0.80	**0.40**
2	1.00	1.00	0.20	1.00	0.40	**0.72**
3	0.00	0.20	0.40	0.20	0.60	**0.28**
4	1.00	0.40	0.80	0.40	0.20	**0.56**
5	1.00	1.00	1.00	1.00	0.20	**0.84**
6	1.00	1.00	1.00	1.00	0.60	**0.92**

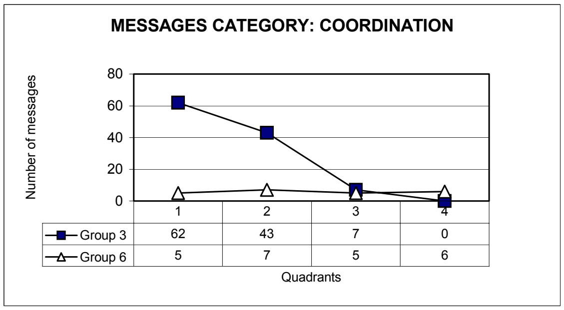

Figure 2. Coordination messages of groups 6 and 3 throughout the labyrinth quadrants.

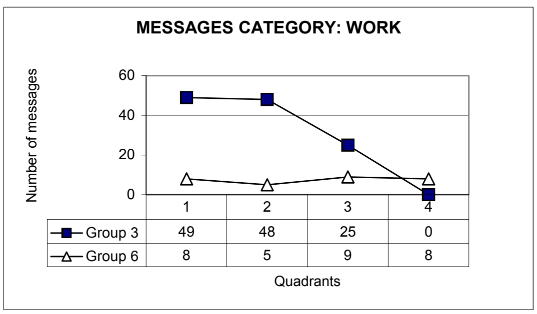

Figure 3. Work messages of groups 6 and 3 throughout the labyrinth quadrants.

measured by three factors: fewest errors done by the group (related to the best score), achievement of the main goal (the group can solve the labyrinth) and fewest 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 they reach the goal (cheese) or loose the game (a partial score goes down to zero). In this view, the "best" group does the Work faster. The Work is reflected by the amount of messages sent by the members of the group.

Table 3. Final product evaluation.

Group	Quality	Time	Work	Average
0	0.87	0.86	0.22	0.65
1	0.50	0.82	0.40	0.57
2	0.95	0.99	0.13	0.69
3	0.52	0.67	0.72	0.63
4	0.62	0.42	0.95	0.66
5	0.74	0.83	0.27	0.61
6	0.56	0.81	0.19	0.52

Table 3 summarizes the results (average value) obtained by the groups, notice that the "worst" group, according to Table 3, is the group 6, which is the group that obtained the best IC in the collaboration process evaluated in the previous sections (Table 2).

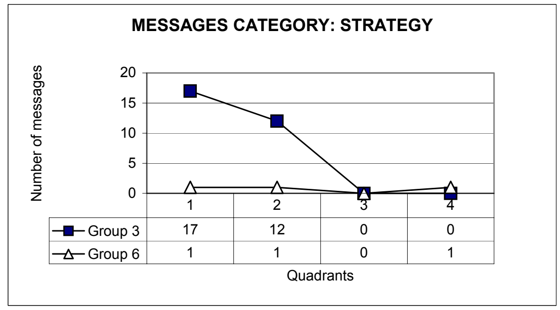

Figure 4. Strategy messages of groups 6 and 3 throughout the labyrinth quadrants.

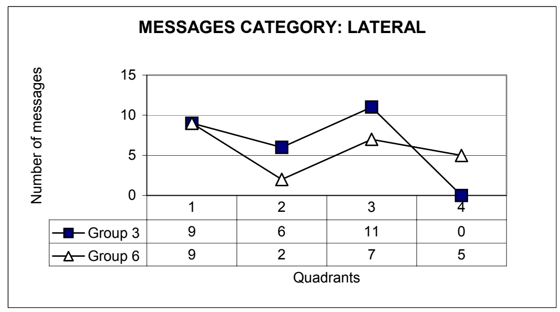

Figure 5. Lateral messages of groups 6 and 3 throughout the labyrinth quadrants.

8. Conclusions and further work

In this paper we presented a software tool that allowed us to enable a collaborative work computer-based activity, and to gather information concerned to it, in order to evaluate the cooperation proccess that occurs in the group work. For the evaluation of the cooperative *procces*, we have identified five cooperation indicators, wich in turn allow us to define a *cooperation index*. As well, to evaluate the outcome of the group work, we used three factors: Quality, Time, and Work.

As a major conclusion we can say that the *process quality* of the work group is not directly related to the *final product quality*. In this experiment, the group that has the best results in the process quality evaluation has the worst in the product quality measurement.

It is also important to headline that the cooperative work process is influenced by the personal style and individual behavior of every member of the group. We can observe a stability in the performance of the tasks accomplished by each one of the group members, as much in their coordinator role like in their collaborator role. This stability is also observed in the personal styles and communication skills.

The results suggest that the shared construction of a strategy to fullfill a group work, understood and adopted by every member of the group, is related to a successful process, to the individual construction of cognitive context, and to the experiences shared by the group members. Also, it enhances the elaboration process of strategies and facilitates its application. This fact is reflected in the performed lenguage utterances: those are homogeneous, direct and unambiguous when refered to the common problem features.

There is a direct relationship between the control activities (coordination messages) and the execution of the task (work messages) beyond its final result (success or failure). This suggests that those variables do not forecast a satisfactory result for the group, it is a clear understanding of the problem and the solution strategy which lead to a success process. In this way, if every member of the group understands the problem, they will require less communication efforts. Besides, too much communication, not focused in the major goals, has a negative effect into the accomplishment of the goal (disturbance, cognitive overload, etc.).

Finally, is important to notice that the four categories identified (coordination, work, strategy, and lateral messages) give us significative insights into the interaction process embedded in a group work, wich pursuits a goal and a concrete objective, and requires the attention and participation of every member of the group.

As for further work, we'll improve the interface design of the tool and will use it in more experiments. This will allow us to obtain a significative amount of data to analyze and compare, in order to generalize our observations.

Acknowledgements

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