Evaluating Collaborative Learning Processes

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Abstract. Understanding and analyzing collaborative learning processes require a fine-grained sequential analysis of the group interaction in the context of learning goals. Several researchers in the area of cooperative work take as a success criterion the quality of the group outcome. Nevertheless, recent findings are giving importance to the quality of the cooperation process itself. This paper presents a set of indicators which main objective is to evaluate the collaborative learning process. We have defined an experiment with a tool instrumented to gather data from groups working in a simple task. This data is then useful to build the cooperation indicators, which in turn allow us to estimate the quality of the work process.

1 Introduction

Dillenbourg *et al.* claim 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 [7]. 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 [1,7,27]. Recent research, however, is giving emphasis to the study of collaboration *processes* and their support [3,4]. The work reported in this paper concerns the collaboration processes.

Collaborative learning is a complex phenomenon, and studies are being conducted from many different analytical levels and from a range of various theoretical and methodological perspectives. Understanding group dynamics, and the collaborative processes of decision making and learning in groups, is important for both learners and instructors in collaborative learning programs. Understanding and analyzing the collaborative learning process requires a fine-grained sequential analysis of the group interaction in the context of learning goals. We may notice that supporting individual learning requires an understanding of individual thought process, whereas supporting group learning requires an understanding of the process of collaborative learning [23].

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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 the "cooperation process" itself. Success in collaborative learning subject matter means both learning the subject matter (collaborating to learn), and learning how to effectively manage the interaction (learning to collaborate). The knowledge acquisition process for systems supporting collaborative learning warrants a closer look in light of this additional complexity [24]. Traditional instruction tends to emphasize the product of the design and development process, but not the process itself [19].

The typical 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, a quantitative evaluation of the *quality of the outcome* is done. Some techniques of cooperative learning use this strategy (e.g. "Student Team Learning" [24], "Group Investigation" [25], "Structural Approach" [17] and "Learning Together" [13]). Nevertheless, little investigation has been done to evaluate *the quality of the collaboration process*.

Taking into account the characterization of cooperative learning presented by Johnson & Johnson [16], we further develop the Index of Collaboration proposed by Guerrero *et al*. [10], by defining a set of indicators. These indicators are intended to help in the evaluation of the collaborative learning process. We have defined an experiment with a tool instrumented to gather data useful to build these cooperation indicators, which in turn allow us to estimate the quality of the work process.

This paper is organized as follows. In section 2, we present some related work. Section 3 presents the Johnson & Johnson characterization of collaborative learning processes. In section 4, we propose an evaluation instrument. Section 5 describes the metrics we used. Section 6 introduces the cooperation indicators as well as a method that allows us to evaluate some key points identified in the phases of collaborative learning. Section 7 describes the experimental design. An analysis of the results is done in Section 8, and finally, section 9 presents some conclusions and proposals for future work.

2 Related Work

Since the advent of computer supported collaborative work, the investigation of computer supported collaborative learning has been of major interest. It has been conclusively argued that a focus on the process of collaboration is necessary in order to understand the value of working together with peers for learning [21]. Collaboration is the mutual engagement of participants in a coordinated effort to solve a problem together [22].

Various approaches for analyzing group learning interaction have been proposed. Some of them are presented below to have an overview of how this interaction is considered from different perspectives.

Barros and Verdejo [3] have proposed an asynchronous newsgroup-style environment enabling students to have structured, computer-mediated discussions on-line. Evaluating the interaction involves analyzing the conversation to compute values for the following four attributes: initiative, creativity, elaboration, and conformity. Katz *et al*. [18] developed two rule learning systems, String Rule Learner and

Grammar Learner. These systems learn patterns of conversation acts from dialog segments that target particular pedagogical goals. Inaba & Okamoto [11] describe a model that draws upon the ideas of finite state machines and utility functions. They used a finite state machine to control the flow of conversation and to identify proposals, while applying utility functions to measure participants' beliefs with regard to the group conversation.

Muhlenbrock and Hoppe [21] have developed a framework system for computer-supported cooperative learning and working. The system has been used in determining conflicts in focus setting as well as initiative shifts in aggregation and revision phases during some collaborative sessions on problem solving. Constantino-González *et al*. [5] developed a system that evaluates a new approach to supporting collaboration that identifies learning opportunities based on studying differences among problem solutions and on tracking levels of participation.

Soller & Lesgold [23] have developed an approach to analyze collaborative learning using Hidden Markov Models. Additional work is needed to understand how students communicate and collaborate, and to apply this knowledge to develop computational methods for determining how to best support and assist the collaboration learning process. This is our rationale to propose a set of indicators in order to understand the collaborative learning process. Next there is an explanation on how we defined our set of indicators, based on the stages of cooperative learning processes presented by Johnson & Johnson in [1].

3 Stages of Cooperative Learning Processes

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 accompli-shed entirely by the facilitator. The tasks concerning the *in-process* phase will be performed, to a large extent, by the group members. It is here where the interactions of *cooperative work processes* take place. Thus, our interest concentrates in the evaluation of this stage. In order to specify this division, we present the structure of a cooperative learning activity identified by Johnson & Johnson in [1], and next we classify each activity according to the stage we are proposing[2]:

1. Design the content and main tasks objectives to be accomplished by cooperative groups (pre-process).
2. Specify the size of the groups. It has been suggested to be up to 6 people depending on the nature of the task and the time available (pre-process).
3. Build the groups. Assign the students to conform each group or allow them to form the groups by their own (pre-process).

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

4. Arrange the room for the cooperative learning activity. The facilitator must be "attainable" by every group and their members can seat together without interrupting other groups (pre-process).
5. Distribute the instructional material. This can be achieved in several ways (pre-process).
6. Design roles, such as: speaker, facilitator, recorder, executor, and observer (pre-process).
7. Specify the directives of the task: the facilitator must 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. The facilitator must 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 at the end of the activity (post-process phase).
17. Encourage students to perform an evaluation on how well the group works 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 the in-process phase).

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 next section introduces a software tool used to get raw data which will be elaborated by the collaboration indicators.

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		Present the activity closure
Arrange the groups	Intra-group cooperation	Evaluate the quality of learning
Arrange the room	Probe the success criteria	
Distribute the material	Monitoring	
Design the roles	Provide help (from facilitator and from peers)	
Specify the game rules	Intervention in case of problems	
Define the success criteria	Self-evaluation of the group	
Determine the desired behavior	Feedback	

4 Chase the Cheese

Since our goal is to study the collaborative learning process, we developed a tool to capture data from groups engaged in such type of learning. We chose a small case in which a group of persons have to do some learning in order to do a joint task. The task is a game of the labyrinth type.

The 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.

4.1 System Functionality

Figure 1 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 obstacles location 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 1, she can send messages to the players with blue, red and green colors.

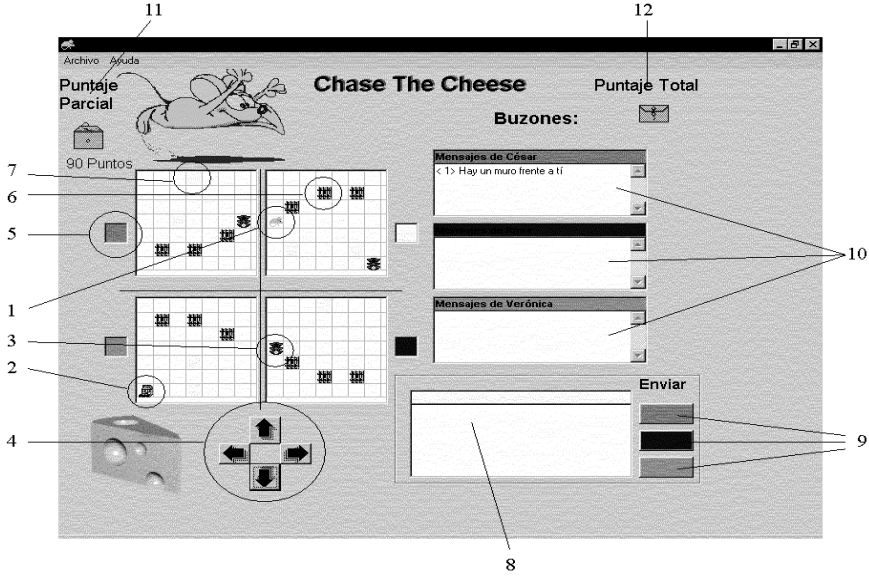

Fig. 1. Chase the Cheese game interface.

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 then, is 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).

4.2 Gathered Information

The application has a structured chat-style user interface, through which the group conversation is held. The application records every message sent by any member of the group. Along with each message, it records the time of occurrence, sender, addressee and current quadrant (the mouse location –X and Y position– when the message was sent). The Figure 2 shows an example of the information gathered by the application. 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 each player looked at the partial and total scores by quadrant.

X	Y	Quadrant	From	To	Message	Time
1	1	1				
			Andres	Gaston	I need your coordinates	12:00:41
			Andres	Miguel	I need your coordinates	12:00:52
			Andres	Sergio	I need your coordinates	12:01:13
			Miguel	Andres	A2 and F4	12:01:25
			Gaston	Andres	A5 and G5	12:02:08
			Andres	Gaston	D3 and g3	12:03:13
			Sergio	Andres	ok	12:03:21
1	2	1				
			Miguel	Andres	Letters are arrows	12:04:32
1	3	1				
2	3	1				
2	4	1				
2	5	1				
3	5	1				

Fig. 2. Log file content.

5 Metrics

In order to analyze each one of the indicators, we define some metrics, that are indicators of system, user, and group performance that can be observed, singly or collectively, while executing group activities. Metrics –such as time, length of turn, and other countable events– are directly measurable and can often be automatically collected [8].

The following table of metrics includes the observable data elements that were identified as useful indicators of system and group performance. For each metric, we present definitions and some examples of ways to capture the metric in Table 2.

6 The Indicators

Guerrero *et al*. [10] have defined an Index of Collaboration based on the structure of a cooperative learning activity explained above in section 2 (in-process phase). That

Table 2. Metrics

Metric	Meaning	Example
Number of Errors	Total hits over an obstacle.	
Solution to the problem	The group is able to solve the game.	
Movements	Number of mouse movements	
Score checks	Total number of checks to the scores	
Use strategy	Outline a strategy for the problem solution in an explicit way.	
Maintain strategy	Use the defined strategy during all the game	
Communicate strategy	Negotiate, reaching consensus and disseminate information about strategy.	
Strategy messages	Messages that propose guidelines to reach the group goal.	“Let's label the columns with letters and the rows with numbers”
Work strategy messages	Messages that help the coordinator to make the most suitable decisions. These are sentences in present tense and their goal is to inform the group about the current state of the group task.	“Stop, there is an obstacle in B3".
Coordination strategy messages	Messages that correspond to activities which main purpose is to regulate the dynamics of the process, and are characterized by prescribed future actions.	"I will move six squares to the right".
Work messages	Messages received by the coordinator.	
Coordination messages	Messages sent by the coordinator.	
Success criteria review messages	Messages that review the boundaries, guidelines and roles of the group activity.	
Lateral messages	The kind of particular messages (i.e. social messages, comments) and conversations that are not focused on the solution of the problem.	"Come on, hurry up, I'm hungry!!!!!!! ".
Total messages	Total number of messages received and sent by the group during the activity.	

Index was the simple average of five identified indicators based on some activities proposed by Johnson & Johnson in [1].

In this work, we present a refinement of that Index of Collaboration, defining a set of indicators which main objective is to evaluate the collaborative learning process. Four of the indicators are based on the following activities proposed by Johnson & Johnson in [1]: use of strategies, intra-group cooperation, checking the success criteria, and monitoring. The fifth indicator is based on the performance of the group. Each one of these indicators is explained below.

6.1 Applying Strategies

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. According

to Johnson & Johnson in [1], to apply a strategy is "to produce a single product or put in place an assessment system where rewards are based on individual scores and on the average for the group as a whole".

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 (see Dillenbourg definition of *collaboration* [7]). 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 [9], 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 [12].

In general, the specific measure 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 keep the chosen strategy during the game development, 30% for quality of the strategy communication, and 5% for other quality measures. The other quality measures included number of errors made by the group (related to the score) and number of mouse movements (related to efficiency).

6.2 Intra-group Cooperation

This indicator corresponds to the application 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 [6]. 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 % application of collaborative strategies and 20% providing help. Measuring the application of collaborative strategies implies the evaluation of coordination procedures and assessing the degree of joint understanding of the strategy. A good application 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.

6.3 Success Criteria Review

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.

6.4 Monitoring

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)).

6.5 Performance

Baeza-Yates and Pino [2] 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 lose 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).

7 Experimental Design

The experiment has four phases. The group receives a brief description of the software tool. During the second phase, group members are assigned to network workstations, in separate rooms (synchronous distributed interaction). From then on, all communication is mediated by computer. During the third phase, the group will try to solve the labyrinth. Finally, the fourth phase corresponds to the gathering and analysis of data recorded by the tool. We made also a final interview to the participants to foster a self-evaluation of the experience. This gave us a general overview of the problem perceived by each member of the team.

So far, we have applied the experiment to eleven groups, as follows:

- A group of graduated students, from the course "Collaborative Systems" at Pontificia Universidad Católica de Chile, with some experience on collaborative work techniques (group 0).
- A group of people, randomly selected, who have not met before and, of course, they have never worked together (group 3).
- A group of friends who have worked as a group many times before the experience and have a good personal relationship (group 4).
- Four groups of high school students from Cumbres de Santiago School, 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).
- Four groups of graduate students from Universidad de Chile (Groups 7,8,9,10).

8 Results Analysis

8.1 Applying Strategies

The objective is not only to show which group got the best or worst score, but to analyze each one of the elements that are part of this indicator and so, determine why some groups are better than others. Table 3 shows the results.

From the collaborative work viewpoint, effective groups have goals which are clarified and modified as follows. There should be the best possible match between individual and group goals. They are also cooperatively structured so all members are committed to reach them. The results show us that groups are ineffective because communication was poor even though they have high "maintain strategy" scores. We can infer that members accept competitively structured imposed goals, so each member attempts to achieve her personal goal first.

Table 3. Applying strategies results

Group	Solution	Use	Quality	Maintain	Communicate	CI1
0	1	1	0.62	0.62	0.36	0.69
1	0	0	0.5	0.68	0.41	0.31
2	1	1	0.95	0.65	0.26	0.68
3	0	1	0.52	0.59	0.36	0.48
4	1	1	0.87	0.64	0.37	0.71
5	1	1	0.74	0.74	0.43	***0.75***
6	1	1	0.56	0.71	0.35	0.71
7	1	0	0.5	0.60	0.32	0.47
8	0	0	0.4	0.61	0.35	*0.27*
9	0	0	0.4	0.65	0.35	0.28
10	1	0	0.5	0.62	0.34	0.48

We could not find that conflicts of interest were solved through integrative negotiation and agreement, that is to say there is not a mediated process. It was common to observe that the first coordinator tried to impose her viewpoint and the rest of the group members simply followed her instructions. The initial imperative messages typically were: “Let’s label the columns with letters and the rows with numbers”, or “I will move first and then you are going to send me your coordinates”. It was not frequent to find messages that could induce to negotiate a position, like: “I propose that our strategy be... do you agree?” or “What do you think?” So, we can observe that the communication is not two-way and open with the possibility of expressing feelings as well as ideas. On the contrary, it usually was one-way, where only ideas were expressed and feelings were ignored.

The group that got the best score was group 5 (CI1= 0.75), so, we could think that it is a good group in this aspect (applying strategies), but if we analyze in detail this indicator, we can infer this is a good work group, but not a good collaborative group. Group 5 is ineffective as collaborative group because the group could not build an effective communication method among members in spite of the best score in the maintenance aspect. In a collaborative activity, it is not only important to understand the problem, but to share that understanding among teammates, and this was Group 5 weakness. Compare this group with Group 8, which got the worst score (CI1=0.27), but it uses a better strategy (according to our quality metric) and it maintains it. Group 8 is one of the groups trying to promote some kind of discussion around the strategy definition; unfortunately, the final decision is imposed without a participatory negotiation.

It was common to find groups that even after defining a strategy for the first quadrant, with some members of the group understanding that strategy, did not obtain a high score. The explanation lies in the lack of strategy understanding by *some* members of the group. We could observe, e.g., a group in which two of the members understood the strategy, and in fact during the first two quadrants the partial results were very good. The problem appeared in the third quadrant, because the corresponding coordinator –who had not fully understood the strategy– began to make some movements according to her viewpoint, and obviously the group could not solve the labyrinth. In this case, the members who understood the strategy did not care to make sure the rest of the group did also. So, it is not only important to understand the

problem, but to be aware that the rest of the people can understand the problem situation during a collaborative learning activity.

The team learning potential is maximized when all group members participate in the group discussions. Building involvement in group discussion increases the amount of information available to the group, enhancing group decision making and improving the participants' quality of thought during the learning process [12]. For this reason, encouraging active participation could increase the likelihood that all group members understand the strategy, and decreases the chance that only a few participants understand it, leaving the others behind. Unfortunately, none of the observed groups behaved in this direction and therefore, one wonders if this aspect of learning is not spontaneous, at least in a first session of collaborative learning.

8.2 Intra-group Cooperation

This indicator provides information about the application of collaborative strategies defined in Section 6.2. Table 4 shows the results.

Table 4. Intra-group cooperation results

Group	CI2
Group 0	0.69
Group 1	0.71
Group 2	0.62
Group 3	*0.61*
Group 4	0.74
Group 5	**0.84**
Group 6	0.72
Group 7	0.80
Group 8	0.75
Group 9	0.75
Group 10	0.80

Concerning this indicator, we can observe that almost all groups got a good score. These results show us there was an interest to solve the problematic situation among all members of the groups. It was common to observe that when someone asked information about something, the other members of the group were able to solve her doubts. Therefore, all questions –when asked– were solved by all group members.

Analyzing and observing the members' actions, we could find a dialogue pattern. When a participant requested help, at least she received one answer from the rest of the participants. It is important to note that these answers were timely. One of these patterns is shown below.

Coordinator: *Can I move to the right?*
Player 2: *I don't have obstacles.*
Player 3: *I don't have obstacles.*
Player 4: *There is an obstacle in that position.*

All the answers were given in a small time interval. Thus, the coordinator could infer what movement she could do and all participants are helping to solve the problematic situation.

Members of the group who are not influenced by promotive interdependence engage in promotive interaction; they verbally promote each other's understanding through support, help and encouragement [15]. In the experiments, it was common to observe that if a member of the group did not understand the answer to a question or solution to a problem, her teammates made special reinforcements, sending messages like: "Remember, you need to send me the location of your obstacles" or "You can not move", to address her misunderstanding before the group moves on. Ensuring that each member of the group receives the help she needs from her peers is key to promoting effective collaboration interaction. Thus, for our groups we can conclude all of them were good according to this indicator.

8.3 Success Criteria Review

This indicator gives information about the interest of members to check their roles, performance, results in order to achieve the main goal. Table 5 shows the results.

Table 5. Success criteria review results

Group	CI3
Group 0	0.2
Group 1	0.2
Group 2	0.2
Group 3	0.5
Group 4	0.8
Group 5	***1***
Group 6	***1***
Group 7	*0.2*
Group 8	*0.2*
Group 9	*0.2*
Group 10	*0.2*

This indicator provides an understanding of the performance analysis the group did during the group activity. Group processing and performance analysis exists when groups discuss their progress, and decide which behaviors to continue or change [15]. So, it is necessary that people evaluate the previous results obtained in order to continue, evaluating individual and group activities, and provide feedback. It is necessary also members of the group take turns questioning, clarifying and rewarding their peers' comments to ensure their own understanding of the team interpretation of the problem and the proposed solutions. "In periods of successful collaborative activity, students' conversational turns build upon each other and the content contribute to the joint problem solving activity" [28]. Unfortunately, this did not happen with the analyzed groups.

If we look at the results, we could infer there were some groups who had a perfect performance in this indicator (groups 5, 6). However, if we observe in detail the objective of this indicator, and observe the group logs, we can conclude that this aspect was not fulfilled as we would like. The results we got are relative scores, that is to say, according to the analyzed groups, the best group were 5 and 6, but that does not mean they are good groups. According to this indicator, it only reflects we need to do additional experiments in order to determine the "ideal group", and according to that group make relative comparisons. The groups with the best score were groups that reviewed the partial and total score during the process of collaborative activity, but rarely or never, were interested to evaluate the results obtained in order to re-define the next movements, or to provide some feedback to the members of the group. It was unusual to find messages like: "We are losing, our score is decreasing, so we need to define our next movement". Only two groups (5, 6) had some messages like: "Our score has increased", "We are losing", but unfortunately, these groups did not stop to analyze their performance, to clarify issues and to define a new model of solving the problem situation.

8.4 Monitoring

This indicator gives an understanding of how the group maintains the chosen strategies to solve the problem. Table 6 presents the results. They show that members of the groups are interested on being consistent about the strategy, so there is a direct relation between this indicator and the aspect of maintenance within Applying strategies indicator (e.g., the group that got the best CI4, got the best score in the maintenance part of CI1). Also, it should be noted that the groups which best scored in this aspect were the ones having a history of working together for some time, so they had good internal relationships. The numerical values for this indicator should be taken with caution, because they are not absolute values; they just serve to compare groups, they are comparative.

In cooperative learning groups, members are required to acquire group skills, like how to provide effective leadership, decision-making, trust-building, communication and conflict-management [15]. The combination of knowing how to manage intellectual disagreements and how to negotiate/mediate conflicts among participants' wants, needs, and goals ensures that the power of cooperative efforts will be maximized. The productivity of groups increases dramatically when members are skilled in how to manage conflicts constructively. Some groups participating in the experiment had worked together before, but still had the characteristics of "work groups" and were not collaborative groups. It was common to find, according to the analysis of the messages, that leadership was delegated and based upon authority, participation was unequal with high powered members dominating. These characteristics are typical of ineffective collaborative groups [20]. The same analysis gave us an understanding of the role of the coordinator in every quadrant. Its function should have been to contribute to maintain the harmony within group, avoiding negative discussions or conflicts, and promoting creative conflicts. Cooperation and conflict go hand-in-hand [16]. The more group members care about achieving the group goals, and the more they care about each other, the more likely they are to have conflicts with each other. The way conflict is managed largely determines how successful

cooperative efforts tend to be. For this reason, we can conclude that our groups still functioned as work groups. They had not acquired the collaborative status yet.

Table 6. Monitoring results

Group	CI4
Group 0	0.75
Group 1	0.80
Group 2	0.80
Group 3	0.74
Group 4	0.78
Group 5	**0.86**
Group 6	0.85
Group 7	0.80
Group 8	0.82
Group 9	0.81
Group 10	0.83

8.5 Performance

Our last indicator provides an understanding of the fulfillment of the group. It provides an evaluation estimate of the groups' outcome, according to its definition in Section 6.5. Notice that the groups which got the worst score were the groups that almost got the best score for the other indicators (see Table 7). That observation provides a hint that the task performance of a group is not related with its learning.

9 Conclusions and Further Work

Understanding group dynamics and the collaborative process of decision making and learning in groups are both interesting research fields and the basis for new tools to support the findings. In the case of collaborative activities, performing well a task implies not only having the skills to execute the task, but also collaborating well with teammates to do it.

In this paper we have presented a software tool allowing us to make experiments on the subject of collaborative work. We could gather information on them in order to evaluate the cooperation processes occurring in the group work. For their evaluation we proposed five cooperation indicators. We do not claim these are the only or best indicators that could be developed to this end. These indicators are not independent either; e.g., there is a relationship between the monitoring indicator and the maintenance of the strategy, and another one between intra-group cooperation and communication of the strategy. The important conclusion is that these five indicators did provide some insight on the collaborative work done by the groups. They can be used to detect group weaknesses in their collaborative learning process.

The analysis of the results suggests the shared construction of a strategy to fulfill a group work –understood and adopted by every member of the group– is related to a

Table 7. Performance results

Group	Quality	Time	Work	CI5
0	0.87	0.86	0.22	0.65
1	0.5	0.82	0.4	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*
7	0.5	0.87	0.23	0.53
8	0.4	0.81	0.4	0.54
9	0.4	0.82	0.4	0.54
10	0.5	0.78	0.3	0.53

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 language utterances: those are homogeneous, direct and unambiguous when referred to the common problem features.

The studied groups were ineffective collaborative groups because they were weak in collaborative attitudes. 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 [14]. 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.

One could guess that a reduced number of work messages would imply a better coordination within the group and thus, one would find few coordination messages. This would occur because many messages would have an effect of cognitive overload, disturbances, etc. Our results support this relationship of number of work messages with number of coordination messages. However, again, well coordinated groups are not necessarily collaborative groups.

It is also important to note that the cooperative work processes are influenced by the personal style and individual behavior of every member of the group. In our groups, it can be observed stability in the performance of the tasks accomplished by each of the group members, in both role types: coordinator and participant. This stability is also observed in the personal styles and communication styles.

Further work is needed to study the influence of many variables we did not isolate in this experimentation. Such variables may be: genre (whether or not this factor has an effect on the results), age, culture, homogeneous vs. heterogeneous groups concerning the previous variables, etc. Other experiments could also be made changing the game. One of these changes may be allowing broadcast messages, or

allowing the group to slightly modify the rules of the game (e.g., forcing the coordinator to receive all messages from members before enabling moves).

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