Designing Collaborative Learning Environments using Digital Games

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Abstract: Collaborative learning environments require carefully crafted designs –both technical and social. This paper presents a model describing how to design socio-technical environments that will promote collaboration in group activities. A game was developed based on this model. This tool was used to conduct experiments for studying the collaborative learning process. Testing with this system revealed some strengths and weaknesses, which are being addressed in the on-going research.

Keywords: Collaborative Learning, CSCL, Model Design, Collaborative Games.
Categories: K.3, K.3.1, K.3.2

1 Introduction

Quantitative research in CSCL is hard to conduct because quantitative measures of collaborative interactions tend to lose the collaborative context [Stahl, 02]. There are many causes for the difficulty of measuring the collaboration processes [Collazos, 07]. However, advantages of collaborative learning are clear and they are well documented [Johnson, 86, Slavin, 88]. The design and measurement of collaborative activities continue playing a key role on both: (a) the learning results that can be obtained and (b) the improvement capability of such activity. Currently there are several proposals to design or measure collaborative processes in learning environments; however, there are just few ones able to integrate these two key elements. Unfortunately, these integrated proposals are complex to apply; therefore, it is not clear they can be used by most teachers and instructors.

This paper presents a model to guide the design of socio-technical environments to promote collaboration in group activities in order to deal with these challenges. A collaborative learning environment was designed using the model, and it was applied in a real scenario. The model allowed us to determine the interactions among subjects, the initial conditions and the design of the shared workspace structure.

The proposal also includes a set of indicators that have shown to be useful to measure collaboration in learning environments [Collazos, 03a]. These indicators complement the design model, allowing teachers and instructors to measure and analyze the students' performance. Thus, it is possible to design effective collaborative learning environments (CLE).

Next section presents some related work. Section 3 describes the model for designing environments that promote collaboration. Section 4 introduces the collaborative indicators to be used to measure and analyze collaborative learning activities. Section 5 presents the CLE which was designed using the model. Section 6 shows and explains the experimental results obtained using this CLE. Finally, Section 7 presents the conclusions and further work.

2 Related Work

There is no doubt collaborative games could be useful for learning. The most important issue is to investigate the requirements that game-based learning should satisfy to get the best results. Thus, Di Blas et al. report an experience in which educational, relational, and organizational settings are at least as much important as technology for the success or failure of a collaborative learning case [Di Blas, 05]. They also found the teacher's participation and motivation was crucial. Focusing on the cognitive capabilities and needs of the learner has produced several innovative computer-mediated micro-worlds aimed at helping students learn a specific domain [Anderson, 93]. Activity Theory (AT) [Wertsch, 79] can also be a source of inspiration for designing collaborative learning environments [Gifford, 99]: AT claims that internal activities emerge out of practical external activity and thus the unit of analysis must include the person and the culturally defined environment.

Instead of designing systems that compensate for meta-cognitive deficiencies by becoming increasingly directive, we should develop systems supporting the learner's meta-cognitive activities (or even better, that develop their meta-cognitive skills) [Dillenbourg, 92]. Furthermore, particular forms of interactions are needed to trigger the desired learning mechanisms in collaborative learning environments [Dillenbourg, 99]. 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 [Santoro, 05]. Thus, we need to design the learning task and the learning environment. The design of the learning task needs to draw on the best we know about how people learn, on 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.

3 The Proposed Model

The proposed model involves three interrelated activities. Each of them provides feedback that allow designers to establish the best design of the collaborative learning environment (Figure 1). The model attempts to assist collaboration in two ways: establishing the situation in which the collaboration takes place (set up initial conditions), and structuring the collaboration itself through coaching or self regulation (maintaining the collaboration).

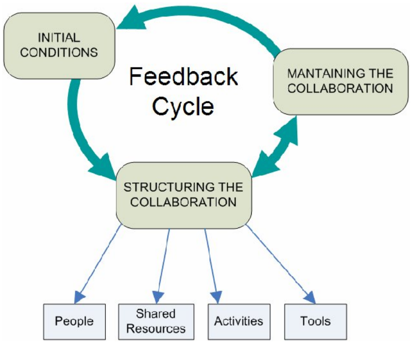

Figure 1. Proposed model for supporting collaboration

The cycle starts with the definition of the initial set of conditions that probably will be present during the collaboration process. Such a definition influences the elements that will be used in the process and the role of each one of them. These two elements establish restrictions on the strategies that can be used for maintaining the collaboration among the participants. The strategies to maintain the collaboration will make a difference between a successful or unsuccessful activity.

As a result of applying this model it is expected the collaborative activity carried out on the learning environment promotes collaboration among group members. Next section describes these three key elements.

3.1 Establishing Initial Conditions

A first way to increase the probability that some types of interactions occur is to carefully design the situation where the collaboration will take place. Numerous independent variables have been studied in order to determine the conditions under which collaborative learning is efficient and effective. Based on Bannon's work [Bannon, 89], the proposed model defines a set of elements to consider for specifying the initial characteristics of the groups. Next, these elements are briefly explained.

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, e.g., include tasks such as: puzzle solving, editing a newspaper or writing a letter.

Nature of collaborators. Specify the types of interaction that occur. It could include three types of interactions: peer-to-peer interaction, teacher-student interaction, and student-computer interaction.

Group heterogeneity. This covers several independent variables such as: size of the group, gender and differences within the group. Typically, the smaller the group, the more each member talks and the less chance there is someone will be left out. Also, smaller groups require less group management skills and they can usually decide faster [Kagan, 92]. Gender specifies the male/female group composition.

Positive interdependencies. This is one of the key elements in successful groups. Based on many studies, psychologists working in education identified positive interdependence as a feature of good learning groups [Slavin, 90]. Collazos et al. have developed various ways of structuring positive interdependencies in software tools based on the interface design to ensure students think “we” instead of “me” [Collazos, 03b].

Setting of collaboration. It corresponds to the place where the collaborative activity will be held. It could be the classroom, workplace, home or a virtual space.

Conditions of collaboration. These conditions specify the kind of mediation. It could be physically co-present or computer-mediated.

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

These elements are instantiated, as it is shown in Table 1, and then they are considered during the collaboration structuring process. Section 4 shows how to instantiate and use these elements to make design decisions.

3.2 Structuring Collaboration

The teacher/instructor cannot simply ask students to start the projects and encourage peers to learn together, but s/he should specify a collaboration process. Such process could include several activities. At each activity, the team has to produce something as a result, and team members have some role to play. The elements we propose to use to design the collaboration process are the following ones:

Activities. This element represents the tasks that must be performed by the group members during the collaboration process. This includes the workflow of (individual and collaborative) activities that make up the process. It also includes the goals and rules of each task. There are activities performed by the group associated to the main goal, and other activities done by every member of the group related to the partial goals. On the other hand, the rules of the group activity should be specified. 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 [Engestrom, 87]. These rules permit reviewing boundaries and guidelines for the activity. The activities included in the collaboration process must be designed so that every member of the group has a similar work load [Kagan, 94].

People. This element determines the roles that should be present in the collaboration process. Each group member has a role to play in each activity. The role assigns responsibilities and grants to the users. For example, a student can play the role of reader in a pair reading exercise. This role will be played for a while, and then it is assigned to the other student of the pair [Johnson, 98].

Tools. This component represents the tools used by people to perform the collaborative activities. These tools must allow collaborators to communicate, coordinate and participate in the process. Members of the group must communicate and coordinate among themselves in order to accomplish tasks that are independent, that are not completely described or that require negotiation [Fussell, 98]. Regarding participation, the idea is to define scenarios where members of the group have the same chances of participation to solve the situation.

Shared Resources. These resources represent the knowledge that is shared by the group members during an activity. This knowledge can include digital objects, a portion of the user interface, coordination strategies, decisions, goals and awareness mechanisms. For example, the discussion of the strategies to solve a problem helps group members to construct a shared view (shared resource) of their goals and tasks required to be executed [Fussell, 98]. This shared view can improve the coordination during an activity, because each learner knows how his/her task matches the global team goals.

These four elements can be used to structure the collaboration process, by considering the constraints imposed by the initial conditions. The goal of this design should be maximizing the knowledge acquired about a subject (learning goal) or the ability of the student to assimilate and reproduce a certain skill (transversal goal), such as negotiation capability or leadership.

3.3 Maintaining the Collaboration

The last aspect to consider is related to the strategy that can be used to maintain the collaboration among members of the group. Such strategy could be coordinated by a cognitive mediator or by the team members themselves.

There is no guarantee interactions among team members actually occur. Hence, some external regulation is needed to promote the occurrence of those interactions. One way to provide that kind of regulation is through the cognitive mediator. The role of mediator will not be to intervene at the task level, but to guarantee all the group members participate, and to frequently ask questions such as: What happened? What does it mean? The role of the cognitive mediator is to maintain the focus of the discussion, guiding students through the knowledge construction process. As the collaboration goes on, the state of interaction is evaluated [Pinheiro, 03]. Remedial actions may be proposed to reduce discrepancies between these states. Indicators that have shown to be useful to measure and analyze the collaboration process in learning environments are presented below.

4 The Indicators

Collazos et al. [Collazos, 03a] have defined five Indicators of Collaboration (IC) that allow measuring and analyzing an activity carried out in a collaborative learning environment. These indicators are the following ones:

Applying strategies (IC1). This indicator tries to capture the ability of the group members to generate, communicate and consistently apply a strategy to jointly solve the problem.

Intra-group cooperation (IC2). This indicator refers to the use of collaborative strategies previously defined during the work.

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 group members, and noting times for expected completion of assignments.

Monitoring (IC4). This indicator is understood as a regulatory activity. The objective of the indicator is to oversee if the group maintains the chosen strategies to solve the problem, keeping focused on the goals and the success criteria.

Performance (IC5). This indicator refers to the quality of the proposed solution to the problematic situation. The evaluation of collaborative work takes 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).

5 The Collaborative Learning Environment

As explained above, a Collaborative Learning Environment (CLE) involves, at least, four elements: people, activities, tools and shared resources. For developing our environment we use a game-based learning approach.

The tool used in our learning environment is a game –called *Chase the Cheese*–, which is played by four persons, each one using a single computer. The computers are physically distant. Thus, the players need to use a computer-mediated-communication tool. All activities made by participants are recorded for later analysis and players are made aware of that. Players are given very few details about the game. The main game rules and obstacles must be discovered by participants while playing. They have to develop joint strategies to succeed.

The game window has four quadrants. The goal of the game is to move a mouse figure (in quadrant 1) to the cheese (quadrant 4). Each quadrant has a coordinator –one of the players– permitted to move the mouse with arrows; the other persons can only help the coordinator sending messages which are seen at the right-hand side of the screen. In this way, each player has two predefined roles: coordinator (only one per quadrant and randomly assigned) and collaborator. In fact, there are four partial goals –one per quadrant- that must be achieved in order to obtain the main goal. The game challenges the coordinator of the quadrant in which the mouse is located because there are obstacles that impede the mouse movements. Most obstacles are invisible to the quadrant coordinator, but visible to one of the other players. This feature of the game must be discovered by the players in order to achieve the goal. The players must then develop a shared strategy to communicate the obstacle locations to the coordinator. Each participant has a partial view of the labyrinth and s/he must interact with her/his peers to solve the problem. Each player (and quadrant) has a colour associated. When starting the movement of the mouse, the coordinator has an individual score of 100 points. Whenever the mouse hits an obstacle, the 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 bridge between quadrants. When the mouse passes to another quadrant the coordinator role is switched, and the previous score is added to the total score of the group. If any individual score reaches a value below or equal to 0, the group loses the game. The goal of the game is to move the mouse to the cheese and to do it with a total score as high as possible.

Let us see how we design the CLE according to the model proposed in the previous section. Table 1 presents the initial conditions in our game software tool. Table 2 presents the way we structured the collaboration among members of the group in our tool.

Elements	Description
Type of activity	Solve a labyrinth
Nature of Collaborators	Peer to peer interaction
Group heterogeneity	The game is played by four people, 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 colourful obstacles.
	Reward interdependence: Group members not only must lead the mouse to its cheese but arrive with the highest score.
Setting of Collabor.	Classroom
Conditions of Collabor.	Computer-mediated
Period of Collaboration	45 minutes

Table 1. Initial conditions for the software tool

Elements	Description
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 gets to 0, the game is over.
People (roles)	Coordinator: one per quadrant.
	Collaborators: the three remaining persons.
Shared Resources (Communication)	The system provides some dialogue boxes, where every participant can send messages to a member or the group. Also, there is a message reception mailbox.
Shared Resources (Participation)	In order to guarantee equal participation of all members of the group, the labyrinth was designed with a similar complexity in every quadrant. The number of obstacles and their distribution was similar in all the quadrants.

Table 2. Structuring the collaboration

The third part of the model (i.e., maintaining the collaboration), includes participation of a cognitive mediator. Our first experiments using this CLE did not include it in an explicit way. We only presented the information at the end of the activity. However, we re-built the collaboration processes through semantic analysis of the messages, and so, we determined the degree of collaboration measured by some IC. The cognitive mediator and/or participants could interpret the results and decide what actions (if any) to take, in order to improve the collaboration [Collazos, 03c]. It could be possible that students, who view and analyze the IC values [Collazos, 03a] may learn to understand and improve their own interaction.

6 Experiments

The designed CLE was used in an experiment involving 11 groups of four students, whom carry out the collaboration process. The groups that participated in the initial experiment were the following ones:

Group 0: A group of graduate students from the "Collaborative Systems" course at the University of Chile, with some experience in collaborative work techniques.

Group 1-4: Four groups of high school students. They were about 15 years old. Two of the groups were randomly chosen (Gr.1 and Gr.2) and the remaining ones included friends (Gr. 3 and Gr. 4).

Group 5: A randomly selected group, i.e., people that have never worked together.

Group 6: Friends who have worked as a group many times before this experiment and that have a good personal relationship.

Groups 7-10: Four groups of graduate students, from the University of Cauca, Colombia (Gr. 7, Gr. 8, Gr. 9, Gr. 10).

Table 3 presents the obtained results. Every IC is computed with a 0-1 range, where 1 means the highest score. Although some groups got a good score in some indicators, we can see that almost all groups were ineffective collaborative groups because they were weak in collaborative attitudes (IC3). The rest of the indicators are acceptable, since most of them are over 0.5.

	IC1	**IC2**	**IC3**	**IC4**	**IC5**
Gr. 0	0.69	0.69	0.2	0.75	0.65
Gr. 1	0.31	0.71	0.2	0.80	0.57
Gr. 2	0.71	0.74	0.8	0.78	0.66
Gr. 3	0.75	0.84	1	0.86	0.61
Gr. 4	0.68	0.62	0.2	0.80	0.69
Gr. 5	0.48	0.61	0.5	0.74	0.63
Gr. 6	0.71	0.72	1	0.85	0.52
Gr. 7	0.47	0.80	0.2	0.80	0.53
Gr. 8	0.27	0.75	0.2	0.82	0.54
Gr. 9	0.28	0.75	0.2	0.81	0.54
Gr. 10	0.48	0.80	0.2	0.83	0.53

Table 3: Experimental Results

Students have two responsibilities in cooperative learning situations: (a) learn the assigned material, and (b) ensure that all members of the group learn the assigned material [Johnson, 78]. 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 carefully think what to do, etc.

By means of educational games, learners should be able to apply factual knowledge, learn on demand, gain experiences in the virtual world that can later shape their behavioural patterns and directly influence their reflection. Learners are encouraged to combine knowledge from different areas to choose a solution or to make a decision at a certain point, learners can test how the outcome of the game changes based on their decisions and actions. Despite the fact our learning environment includes many of the elements proposed in our model the results obtained were not the best. What matters is not just the design of the environment, nor even the design of a single task or curricular unit. Rather, the cultivation of minds, which itself requires engagement in a social process of meaning appropriation, requires the whole environment, not just the computer program, be designed as a well orchestrated whole. This includes key elements, such as curriculum, teacher's behaviour, collaborative tasks, mode of collaboration and interaction, tasks and learning goals.

7 Conclusions and Future Work

The design of well-specified environments could induce collaborative learning activities within a group. Thus, it is important to carefully define every activity that is part of the process in order to promote collaboration. This paper presented a model to design CLE and a set of indicators to measure the collaboration process in such environments. The design model is easy to apply; therefore almost any teacher/instructor could use it. This model attempts to support collaboration in CLEs through two ways: 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).

Based on the obtained results, we believe it is not only important to design the tool supporting the collaboration process, but also to consider other aspects such as teacher's participation and learning goals, in order to have an effective CLE. The use of the proposed indicators allows us to identify strengths and weaknesses of the CLE we designed. It means the indicators are useful to evaluate this kind of learning environments. In addition, the indicators fit with the proposed model, allowing teachers/instructors adjust the CLE based on the feedback given by these metrics. In future versions, we will build tools that allow on-line monitoring the state of the participants' interaction, modelling the state of the interaction, and providing collaborators with visualizations to self-diagnose the collaboration.

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