Dialogue Analysis in Collaborative Learning

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***Abstract*—This paper presents a study about which kind of interaction leads to better learning within a collaborative learning task, in terms of the effects of a speech act on both the actor and their collaborative partner, in a cooperative or competitive behavior. To perform this study, we have developed an analysis model that investigates features in dialogue interactions based on student's differences in understanding, as shown by their conversation protocol, and an investigation of the cognitive conflict based on Piagetian theories. We have analyzed data from a study conducted in a computer supported collaborative learning environment (CSCL) in the domain of fractions. The long-term goal of this model is to better understand collaborative learning and to support pedagogical agents in intervening in dialogue in order to keep collaboration productive.**

***Index Terms*—CSCL, Education, NLP, Assessment, Pedagogical Agents.**

I. Introduction

Nowadays, the education has come across a great challenge. The continuous growth and updates of information that the students need to learn goes beyond our conventional way of teaching. In order to accomplish learning gains, the interaction among students has been studied by the Computer Supported Collaborative Learning (CSCL) community, an important means of implementing constructivist and sociocultural educational approaches. The analysis of interactive processes in collaborative learning dialogues brings actual challenges because of the complexity in dealing with multiple perspectives of assessing the students' knowledge construction.

Many works in CSCL have considered the argumentation as a matter to assess cognitive consequences [1], [2]–[7]. Students can co-construct knowledgeable problem solving by eliciting and discussing concepts and their applicability. Reference [8] has emphasized the significance of argumentation for collaborative knowledge construction. The argumentative process can be generally structured, for example, by the arrangement of different viewpoints, the consideration of objections or the reaction with counter-arguments, and the integration of ideas.

Studies from the 70's have shown that conflict and interaction can promote cognitive development [9]–[13], and can make distinctions between conflict and content [14], which are consistent with Piaget's [15] discussion of the equilibration process. Piaget claimed that one source of progress in the development of knowledge is found in the imbalance that forces a subject to seek new equilibriums through assimilation and accommodation. Reference [14] argue**s** that a critical component of the equilibration process may be simply the conflict between student's beliefs, whatever the content of these beliefs is. This result was accomplished by a series of given erroneous beliefs to the students yielding to stimulate their cognitive growth. From the point of Vygostky's concept of the zone of proximal development (ZPD), the effects of social interaction will always be positive to cognitive functioning [65] when the instruction (the task and the guidance) is in advance (not too far) of the student's current level.

Despite the successful results from these researches, others studies showed difficulties to social and cognitive processes in the collaborative knowledge construction [16]. Some of these studies suggest that social processes can be obstructed because of the quick consensus of the learners instead of the arguing of each other's contributions and integrating ideas [17], [18]. Also, for cognitive processes, collaborative students do not always adopt an objective sequence of steps to reach the problem solving, since they often engage in off-task attitudes [19].

Likewise, contrary to [14], Reference [20] found that students regressed on a task involving a misconception about movement and speed. Reference [21] also found that students may regress in discourse because of the lack of knowledge required for the problem solving. Following this same logical thinking, reference [22] argues that little is known with respect to how argumentative knowledge construction can be facilitated.

Although all these works had studied collaborative learning, none of them have explored the role of the misconceptions in a dialogue protocol, and a detail investigation of the cognitive conflict of ideas based on Piagetian Theory. Thus, we developed a new model [22] approach on the grounds of Austin's speech acts combined with the Belief-Desire-Intention (BDI) agency theory of Bratman [23] and Cohen and Perrault [24] formalized operations for rational actions.

The cognitive change in peer interaction, being either a process of conflict or a process of cooperation, was addressed by Moshman and Geil [25] works as being a false dichotomy. In their findings, the conflicts took place within a cooperative context and not on the students proving their own views as being correct, but co-constructing a consensus solution. Insofar, the conflict can arise from the cooperation.

In this work, we have built an infrastructure [26] that fosters students to learn in a collaborative approach and we

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have developed a dialogue model and a coding scheme [22] for social (studied in another paper [27]) and cognitive dimension. We look at the cooperative and competitive cognitive conflict categories to be analyzed in the protocol. The hypothesis is that conflict can be perceived significant as knowledge gains.

The collaborative learning can be seen as a social game where agents (players) are able to cooperate or compete in order to solve a problem. Yet, in this game, who could actually gain knowledge? The person who cooperates or who competes? The person who sends information or who receives it? This work understands that a detail investigation that searches the role of misconceptions in a dialogue protocol might possibly answer these questions (Fig. 1).

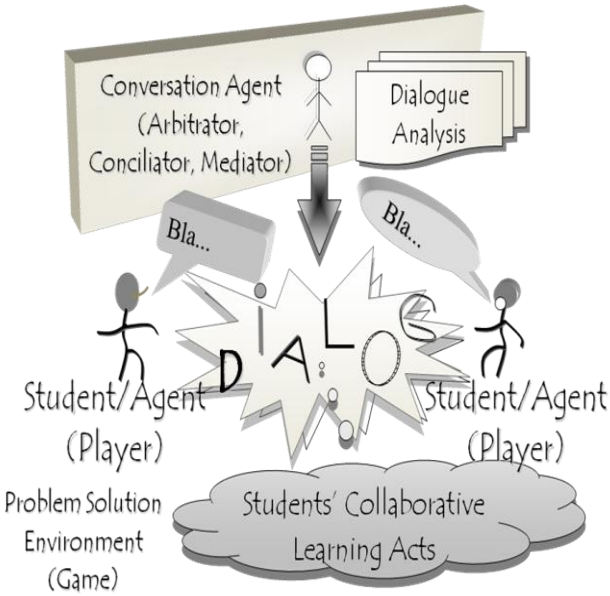

Fig. 1. Collaborative learning dialogue setting.

II. Hypothesis

The main hypothesis is that our coding scheme may predict the individual's knowledge gains on the basis of the students' cooperative behavior through their beliefs' negotiation of their meaning. This data might support the conversational agents to build strategies for maximize the students' gain of knowledge in their conversational process.

It has been found that effective learning in collaborative groups is linked to the process by which learners work on the learning task together [2], how they construct arguments and argumentation sequences [8], [28], and how they build on the contributions of their learning partners [29], [30].

The process of argumentation in a collaborative learning interaction is triggered by the negotiation of individuals' beliefs. Reference [2], for example, categorizes rejections of on-task content as conflict-oriented (see also [18]) consensus building in their multi-dimensional [4] approach to analyze argumentative knowledge construction in CSCL. In the process of argumentation, the individuals balance and imbalance their arguments to attest answers to their problems [31]. For reference [64], the consideration of objections and the reaction to contrary elements are mechanisms that compose the argumentation dialogues. In a learning interaction, these mechanisms can be aroused as misconceptions. For instance, reference [16] identified a gap between what can be observed in discourse and internal processes of knowledge construction, and suggests the examination of this distortion between discourse phenomena and learning by tracing specific misconceptions of learners throughout their collaborative phase. Reference [32] claims the difficulty of conceptual change comes up from the students' lack of awareness whenever they need to shift.

The identification of students' misconceptions could better support the agents in helping the students` be awareness of their incorrect understanding [1]. These misconceptions and the categorization of their types can also provide agents with cues of what, when and how to intervene in the collaborative learning dialogues. For example, the task of a group-learning facilitator is to monitor a large number of on-going collaborative learning discussions and to mediate when necessary to keep the conversation moving in a productive direction [26].

III. Coding Scheme Foundations

Although, Belief-Desire-Intention (BDI) theory has been known as an artificial agents model, its development took place on the basis of folk psychology [33] by which human behavior is explained through the attribution of attitudes, such as believing. Reference [34] ascribed that belief and knowledge can be constructed for machines in a simpler setting than for humans, and later applied to humans. For reference [35], intention is a present commitment to future conduct. In this way, we can think about intentions in order to plan actions towards one's forthcoming state of affairs. Practical reasoning is a model of decision making that springs directly towards actions [36]. Reference [37] identified four important roles in practical reasoning: intentions drive mean-ends reasoning, intentions persist, intentions constrains future deliberation, and intentions influences beliefs upon which future practical reasoning is based. From this discussion, we can note that intentions interact with an agent's beliefs and other mental states. The adoption of intentions brings some implications to our coding scheme. Intention is an attempt to do something to happen. It is attached to our purposes of a collaborative act, since the act of help (collaborate) is an attempt to support someone to do something. It is also linked to our approach of using speech acts, since a collaborative act can be treated as a performative act [38]. We can see the student acting as an agent. If a student has had an intention, then he should seek to achieve it and determine how to achieve it. No further, if a chosen course of action breaks,

A student should usually attempt others, and the agents can help him-her in this process. Students should not cease their intentions until they find the solution or decide that it is a wrong path. Persistence is a positive quality when students are in the right way, agents can pull the students to the correct path, if they are heading towards a wrong one. Agents can also trigger alternatives when students are working straight but cannot reach the goals.

The students can share intentions if they have appropriate interrelation attitudes and a common knowledge task [39]. When people join activities, like in a CSCL, they perform joint actions such as the speech, a communicative act [40]. The meaning of such a speech is a type of intention [41], [42]. The speech act handles the communication as action [38], [43], [44]. Reference [24] formalized two basic operations for rational actions on the basis of beliefs: (1) a speaker's *request* act aims to get a hearer to realize some action, and (2) a speaker's *inform* act aims to get a hearer to believe some statement [37]. In their next work, references [39] and [45] modeled these speech acts as intentions. In our coding scheme, we call these speech acts as the performative [38] verbs *request* and *inform* collaborative acts.

Reference [66] developed multi-modal first-order logic for rational agency based on speech acts and intentions. In this work, the quality of agent persistence is defined as follow: a student has a persistent goal of help (collaborate) *h* if: (1) the student has a goal that *h* eventually becomes true and believes that *h* is not current true; (2) before the student drops *h*, one of the following conditions must hold; (a.) the student believes *h* has been fulfilled, (b.) the student believes *h* will never be fulfilled.

Now, we can define a collaborative peer: consider student (t) to be collaborative to another student (r) if, for any collaborative act of *t* (th) *t* adopts *r*'s collaborative act (rh), on every occasion (rh) would not conflict with (th).

With a collaborative peer, we can define a collaborative act called *request*: a collaborative act *request* is an attempt of a speaker by doing action (a), to bring about a point where, ideally (1) the conversation partner intends to do α (the speaker still requiring a collaborative act, and the conversation partner still collaboratively leaning to the speaker), and (2) the conversation partner actually eventually does α, or at least leads to a point where the conversation partner believes that they mutually believed that they want the collaborative act to happen. Mutual belief happens when among other beliefs alternatives, the students choose to share the same one.

The collaborative act *inform* is also an attempt of a speaker by doing action (a), to bring about a point where, ideally (1) the conversation partner intends to know α (the speaker still wants to *inform* to the conversation partner, and wants the conversation partner to know what he believes), and (2) the conversation partner eventually knows α, or at least leads to a point where the conversation partner believes that they mutually believe that they want the collaborative act to happen.

We can also define the attempt as a complex action that students perform when they do the collaborative acts *request* and *inform* (a) desiring to engender some concept (c) but with the intent to produce at least a response (p) from his conversation partner.

We can start thinking of these two collaborative acts in a meta-cognitive social behavior. For instance, reference [46] defines a social act as any intention which encompasses another self and may be affecting another's emotions, intentions, or beliefs. Social interactions are the acts of people mutually oriented towards each other attempting to influence other's subjective intentions [46]. Therefore, *request* and *inform* collaborative acts are social interactions.

Nevertheless, for reference [47], a shared cooperative activity (SCA) involves each participating agent attempts to be responsive to the intentions and actions of the other, knowing that the other is attempting to be likewise responsive, what is called mutual responsiveness. In our coding scheme, the mutual responsiveness is characterized when students provide each other with their own beliefs (SCA). Thus, *request* collaborative act is an intention of a student attempting to interact with one another. Nevertheless, *inform collaborative act* is an intension of a student attempting to cooperate with one another.

As reference [9]–[13] stated, conflict and interaction promote cognitive development. In CSCL, to a cognitive conflict arises, first the students should provide some belief (*inform* collaborative act). Without a statement they do not have what to discuss about. Reference [48] described conflict as a particular kind of social interaction process between parties who have mutually exclusive or incompatible values. Reference [49] identified 44 models in the area of conflict, we generalized them into two stages. First, a process stage when parties present evidence for their positions (argumentation) about a particular domain [50]; and second a decision stage when evidence is evaluated [51] (consensus).

Hence, based on Piagetian theories for learning the dialogue could and should evoke to parts argumentation. To hold on to argumentation, the students (agents) must have the intention to learn from each other. When constructing arguments students have the intention do convince each other about their beliefs. Therefore, in a collaborative learning protocol some *requests* and *informs* collaborative acts must depict these properties.

Accordingly, we can define the collaborative act *argue* been an attempt of a speaker by doing action (a), to bring about a point where, ideally (1) the conversation partner intends to believe *α* (the speaker still wants to *argue* to the conversation partner, and wants the conversation partner to believe what he believes), and (2) the conversation partner eventually believes *α*, or at least brings about a point where the conversation partner believes that they mutually believe that they want the collaborative act to happen.

Nonetheless, *argue* collaborative act is an intention of a student attempting to convince another one.

IV. Collaborative Learning Act

As reference [52] stated, any study of collaborative processes has to answer two basic questions: (a) the model that refers to which aspects of the collaborative process are relevant, and (b) the methodology that refers on how to assess these process aspects.

It is important for our task to first define what a collaborative learning act is aiming to identify the scope of our work and to build our strategies of assessing it (methodology). To answer this question, we first have to know what our purposes of using a collaborative learning act are (model).

The idea of studying collaborative learning acts comes with a series of investigations to design, implement, and evaluate, conversational agents that play a supportive role in collaborative learning interactions [53]–[55]. The goal is to support collaboration in a responsive manner to what is happening in the collaboration process rather than just react in a pre-defined static manner, which is the case with state-of-the-art of CSCL, such as, assignment of students to roles [56], provision of static prompts during collaboration [16], or design of structured interfaces including such things as buttons associated with typical "conversation openings" [57].

For decades a wide range of social and cognitive benefits have been extensively documented in connection with collaborative learning, which are mediated by conversational processes. Based on Piaget's foundational work [58], one can argue that a major cognitive benefit of collaborative learning comes about when students bring differing perspectives to a problem solving situation, the interaction causes the participants to consider questions that might not have occurred to them otherwise. This stimulus could cause them to identify gaps in their understanding, which they would then be in a position to address. This type of cognitive conflict has the potential to lead to productive shifts in student understanding. Similarly, other cognitive benefits of collaborative learning focus on the benefits of engaging in teaching behaviors, especially deep explanation [59]. Another work in the computer supported collaborative learning community demonstrates that interventions that enhance argumentative knowledge construction, in which students are encouraged to make their differences in opinion explicit in collaborative discussion, are capable of improving the acquisition of multi-perspective knowledge [16]. Furthermore, based on Vygotsky's seminal work [60], we know that when students who have different strengths and weaknesses work together, they can provide support for each other that allows them to solve problems that would be just beyond their reach if they were working alone. This makes it possible for them to participate in a wider range of hands-on learning experiences.

These studies in conversational processes yields our collaborative learning acts' purposes on the top of two main issues that the agents' supervision of these student-student interactions must consider to take effect: (1) the construction of knowledge gain that occurs in individuals during these processes, and (2) the disposition that individuals have to interact with their partners aiming to enhance the collaboration process.

The focus on the construction of knowledge can help agents to aim maximization on their knowledge gain while in the conversational process. On the other hand, one of the requirements to maximize the gain of knowledge of individuals is to encourage them to collaborate with each other.

The definition of what a collaborative learning act is should capture both the construction of the individual's knowledge gain in the conversational process, and the disposition of the individuals to collaborate and to reach a consensus regarding to the problem solving process.

Having these issues in mind, we defined a collaborative learning act in the context of a collaborative learning dialogue as any act perceived by the tutor agent which has an intention to be pertinent and effectively help conversation partners to reach a consensus construction of the problem solving, It also allows the students to share their concepts on the subject matter, thus supporting their interaction and providing them with the opportunity to enhance their individual knowledge gains.

V. Coding Scheme Protocol

The categories of the coding scheme were divided in accordance with our hypothesis for the problem solving. The allotment was an attempt to measure the knowledge achievements among pairs. The total coding scheme has 32 categories. For this work, we have selected two categories with cognitive learning significance for the cognitive level. These categories have the intention to convince the partner about a belief been either: *argue* divergent reasoning, and *argue* contradiction.

In table 1, we categorize these two knowledge misconceptions. The encouragement to elaborate these categories emerges from the student's interaction dialogues analysis, and the studies of [61].

TABLE I: Categorization of Knowledge Misconceptions

Intention to Convince Partner	Knowledge Meaning	Sketch Form	Example
Argue Divergent Reasoning	The speaker approaches his partner's solution to the problem expressing a negative sentence and identifying the concept that he/she is contrary.	This concept is wrong!	That's not the common denominator!
Argue Contradiction	The speaker approaches his partner's solution to the problem by expressing a logical inconsistency in his/her partner reasoning.	You did this, but the right way is that.	Well it looks like you multiplied 6 by 5 so I bet if you multiplied 5 by 5 you would get the numerator

The contradiction category should provide an improvement feedback from the agent to the students. For instance, if the student says "The division is when I have two numbers and then I add the first number by itself for the number of times of the second number". The feedback for the student should have different cognition effects, if the tutor merely says "that's wrong" compared with, if the tutor says "the concept you are talking about is the multiply concept and not the division one". This special feedback should provide the student with means to better reorganize his ideas about the concept.

The *inform* divergent reasoning category arises conflict of ideas for the peers as does the contradiction one. Hence, we have the hypothesis that these two categories will come up evidence of student's learning gains.

For the analysis of the protocol, we use TagHelper [26]. TagHelper tools package has provided a convenient framework to quantify our success in terms of agreement with the hand-coded gold standard corpus with the help of the Kappa [62] statistic as an accepted standard for measuring coding reliability. The Naïve Bayes classification algorithm was applied to the dialogue data for the thirty two categories depicted in our model, without the options for: remove stop words, remove rare features, and contains non-stopword. The kappa was 0.67 with 73.23% of correctly classified instances (CCI), for a total of 695 instances.

VI. Infrastructure and Methodology

The computational platform was built with the Cognitive Tutor Authoring Tools (CTAT) [63]. The students worked with their school computer lab in pairs using CTAT. The arrangement of the lab was such that the students could not easily talk with their pairs. The identity and the seat of the collaborating pairs were hidden from their partners. The purpose of this arrangement was to foster the students to use only the chat interface while communicating with each other, in such a way that all their expressed collaborative efforts to solve the problems could be stored through their chat dialogues and problem solving contributions to be analyzed later. The collaborative problem solving interface included two panels: a chat, and a collaborative interface for the problem solving (CTAT)(Fig. 2). The panels worked in a real time fashion, in such a way that the actions performed by the students in one of the panels instantly conveyed the updated changes for their partners.

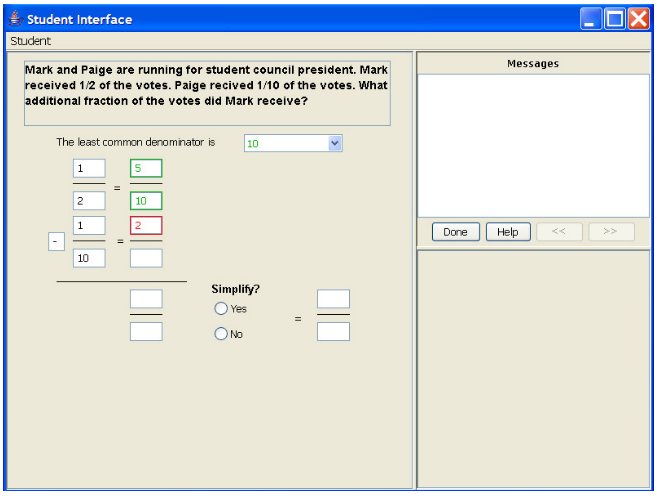

Fig. 2. Problem solving interface.

Thirty two students from a suburban elementary school participated in the study. The students were arranged into pairs.

The materials for the experimental were the following: (a) a mathematics tutoring program covering problems on fraction addition, subtraction, multiplication, and division; and (b) two extensive isomorphic tests were designed for use as pre-test and post-test. Forty nine questions for the pre-test and forty seven questions for the post-test.

The experimental procedure lasted four school days. On the first day, each student took a pre-test to acknowledge how much the students knew about the subject matter. It lasted about 30 minutes. A short collaborative training manual was also provided guiding the students to perform collaborative dialogue. On the second day, which was the first lab day, the students worked together as well as the third day, which was the second lab day. Each lab session lasted forty five minutes. There was a weekend gap between the third and fourth day of the experiment. The post-test was done in the fourth day, which allowed a measure of retention. Each student performed the post-test by him(her)self. Teams remain the same all over the experiment.

The students were guided to work in cooperation by offering a small prize for the teams at the end of the study based on how much they learned about the subject matter, and how much problems they solved correctly working together.

This experiment allowed to investigate the student's knowledge gains based on the pre- and post-tests and to analyze the chat in CTAT contributions based on students' pairs and the students alone. There were a total of twenty four students analyzed that participated in all the investigation process, since the pre-tests throughout the lab days until the end of the experiment with the post-tests. Because one of the students did not participate in the chat interface during the two lab days, we reduced the sampling into twenty three students.

VII. Results

The experiment was a controlled experiment in a realistic setting. The pairs were real classmates and they used material from their actual curriculum. Because of the small number of students, we considered only statistical significance ($p<.05$) effects to assure certainty in our conclusions based on the available data. In this work, we investigated perceived significance by attempting to relate cognitive analysis from the dialogues concerning the sender (self) and the receiver (partner).

The summary of the dialogue analysis based on our coding scheme is shown in Table 2. The measures were the comparison between a gold standard determined by pre- and post-test learning gains and the numbers of sentences related to each category of our coding scheme found in the dialogue discourse.

TABLE 1. The Relationship between Learning Gains and Different Dialogue Acts (P Values Shown). Statistically Significant Results (P<.05).

Category	Self	Partner
Argue Contradiction	0,97	0.01
Argue Divergent Reasoning	0.008	0.70

To receive contradiction (partner) from another student (self) is associated with significantly higher learning gains, $r=0.48$, $t(23)=2.55$, $p=0.01$, for a two-tailed t-test. This result gives evidence that students who received information showing a logical inconsistence in their reasoning had more learning gains. The contradiction category might imbalance the peer's reasoning by forcing them to seek new equilibriums through assimilation and accommodation. This is consistent with Piagetian theory of perturbation, the partner's reasoning is affected by conflicting ideas.

Divergent reasoning (self) to the partner is associated with significantly higher learning gains, $r=0.53$, $t(23)=2.93$, $p=0.008$, for a two-tailed t-test. As the contradiction category, the divergent reasoning category might also imbalance the peers' reasoning by the conflict of ideas.

VIII. Conclusion

The purpose of the analysis of the experiment was to investigate the gains in learning for each role performed by students, self (sender) or partner (receiver), during the collaborative dialogues. For this purpose, we created two categories in our coding scheme with two different roles. The category divergent reasoning is when the sender approaches the solution of the problem that was proposed by the receiver by expressing his disagreement and identifying the concept that the sender is opposing to. The contradiction category is when the sender addresses the solution to the problem proposed earlier by the receiver through a sentence that identifies a logical inconsistency in the reasoning of the receiver's solution.

When the sender has a disagreement (divergent reasoning) in the concept for the solution of the problem, the sender tries to reassert his cognitive ideas that he is in conflict with the solution of the problem proposed by the receiver in their conversation. Thus, according to the theory of Piaget, the imbalance is identified (a reasoning perturbation due to the conflict of ideas) on the own sender of the sentence. However, this category does not guarantee the imbalance in the receiver's cognitive system, because the only thing that the receiver knows is that the sender did not agree with the receiver's solution for the problem. Thus, the receiver does not have the knowledge to understand the reasons of the disagreement with his reasoning. There is a divergentnce in the receiver's mind, but this divergentnce does not have parameters for the receiver to compare to.

In the contradiction category, the sender explains to the receiver the reasons of why he had a failure for the solution of the problem. In this case, the imbalance of the cognitive system occurs only at the cognition of the receiver. The receiver is forced to seek a new balance in his reasoning through the assimilation and accommodation of these new concepts. The sender was already aware of the logical inconsistency of the solution of the receiver, and therefore there is no imbalance in the reasoning of the sender.

For the reasons described above, we consider that the contradiction category is significantly perceived for greater gains in learning only for the receiver (partner). On the other hand, the contradiction category cannot be significantly perceived for greater gains in learning for the sender (self).

All the same, the divergent reasoning category could be significantly perceived for greater gains in learning only for the sender (self). Yet, this category could not be significantly perceived for greater gains in learning for the receiver (partner).

Likewise, we can contrast the two categories with the approaches of cooperation and competition. The contradiction category is an act of cooperation, because the sender (self) is working with the receiver (partner) through the explanation of a logical inconsistency in his reasoning, which is causing a failure in solving the problem. Also, the divergent reasoning category is an act of competition because the sender (self) is still diverging with the receiver's (partner) reasoning. In the same way, the receiver (partner) does not agree with the sender (self), uptil the sentence was sent.

Thus, we could come to a conclusion that when the sender is acting in the dialogue as a cooperative role he can develop knowledge gains for the receiver (partner); and when the sender is acting in the dialogue as a competitive role he can also foster knowledge gains for himself (self).

In this sense, this work is in agreement with the works of Moshman and Geil [25] cited above - the cognitive change being either a process of conflict or a process of cooperation is a false dichotomy. Moreover, we addressed evidences that the cognitive process of cooperation is a learning benefit for the partner, and the cognitive process of competition is a learning benefit for the self.

Further research using CSCL with students from others cultures and countries can be worthwhile.

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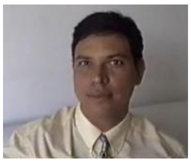

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