Partner or Self, Cooperative or Competitive: Who is the Knowledge Gainer?

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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.

Keywords: CSCL, Education, NLP, Assessment, Pedagogical Agents, TagHelper

1. 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 [3]. However, 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. Otherwise, we developed a new model [1] approach on the grounds of Austin's speech acts combined with the Belief-Desire-Intention (BDI) agency theory of Bratman [4] and Cohen and Perrault [5] formalized operations for rational actions.

Studies from the 70's have shown that conflict and interaction promote cognitive development [6] which is consistent with Piaget's [7] 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.

The cognitive change in peer interaction, being either a process of conflict or a process of cooperation, was addressed by Moshman and Geil [8] 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 [9] that fosters students to learn in a collaborative approach and we have developed a dialogue model and a coding scheme [1] for social (studied in another paper [2]) 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

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that a detail investigation that searches the role of misconceptions in a dialogue protocol might possibly answer these questions.

2. 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.

The identification of students' misconceptions could better support the agents in helping the students` be awareness of their incorrect understanding [10]. 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 [9].

3. Coding Scheme and 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: *diverge reasoning* and *contradiction*.

In table 1, we categorize two knowledge misconceptions. The encouragement to elaborate these categories emerges from the student's interaction dialogues analysis, and the studies of Junqueira, Prata and Costa [11].

Table 1: Categorization of knowledge misconceptions

Knowledge Misconceptions	Knowledge Meaning	Sketch Form	Example
Diverge 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!
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 *diverge 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 [9]. 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 [12] 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.

4. Infrastructure and Methodology

The computational platform was built with the Cognitive Tutor Authoring Tools (CTAT) [13]. 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). 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.

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.

5. 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 2: The relationship between learning gains and different dialogue acts (p values shown). Statistically significant results ($p<.05$) in boldface.

Category	Self	Partner
Contradiction	0,97	**0.01**
Diverge 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.

Diverge 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 *diverge reasoning* category might also imbalance the peers' reasoning by the conflict of ideas.

6. Conclusion and Discussion

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 *diverge 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 (*diverge 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 divergence in the receiver's mind, but this divergence 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 *diverge 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 *diverge 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 [8] 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.

7. Acknowledgements

This work was funded in part by NSF grant REC-043779 to "IERI: Learning-Oriented Dialogs in Cognitive Tutors: Toward a Scalable Solution to Performance Orientation". We also want to thanks Carolyn Rose and Ryan Baker for their support.

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