Analyzing Peer Dialogue from an Active Learning Perspective

Amy Soller and Alan Lesgold

Learning Research and Development Center
University of Pittsburgh
3939 O'Hara Street, Pittsburgh, PA 15260
{soller+, al+}@pitt.edu

Abstract: The aim of this research is to provide an Intelligent Collaborative Learning System (ICLS) with the knowledge and skills to promote effective student interaction in a group. Students learning effectively in groups encourage each other to ask questions, explain and justify their opinions, articulate their reasoning, and elaborate and reflect upon their knowledge. The benefits of collaborative learning, however, are only achieved by active, well-functioning learning teams. The collaborative learning model described in this paper identifies the specific characteristics exhibited by effective collaborative learning teams, and based on these characteristics, suggests strategies for promoting effective peer interaction.

We present the empirical evaluation of two collaborative learning tools that automate the analysis of collaborative learning interaction and activity. Results from our study confirm that effective learning teams are comprised of active participants who demand explanations and justification from their peers. We compare the distribution of conversational skills used by members of a supportive group committed to their teammates' learning to that of an unfocused, unsupportive group. The results suggest that structured, high-level knowledge of student conversation and activity appears to be sufficient for enabling an ICLS to assess the quality of group interaction, furthering the possibility of a system that can support and enhance the group learning process.

1. Introduction

The rapid advance of networking technology has enabled universities and corporate training programs to reach out and educate students who, because of schedule or location constraints, would not otherwise be able to take advantage of many educational opportunities. This new technological capability demands software that can support structured, on-line collaborative learning activities; thus we have recently seen the rapid development of computer-supported collaborative learning (CSCL) systems. CSCL systems offer software replicas of many of the classic classroom resources and activities. They provide on-line presentations, lecture notes, reference material, quizzes, student evaluation scores, and facilities for chat or on-line discussions. Successful distance learning programs around the globe have proven almost all of these tools successful. All but one – the support for on-line learning communication. Chat tools and bulletin boards enable students to participate in on-line discussions, but provide no guidance or direction to students during or after these dialogue sessions.

In the classroom, effective collaboration with peers has proven itself a successful and uniquely powerful learning method [2]. Students learning effectively in groups encourage each other to ask questions, explain and justify their opinions, articulate their reasoning, and elaborate and reflect upon their knowledge. These benefits, however, are only achieved by active and well-functioning learning teams. Placing students in a group and assigning them a task does not guarantee that the students will engage in effective collaborative learning behavior. While some peer groups seem to interact naturally, others struggle to maintain a balance of participation, leadership, understanding, and encouragement. The most effective instructors teach students not only the cognitive skills necessary to learn the subject matter, but also the social skills they need to communicate well in a team. Students learning via CSCL technology need guidance and support on-line, just as students learning in the classroom need support from their instructor. Educational environments that embrace intelligent assistance, designed using a sound psychological model of social interaction, free the instructor from having to coach students both on-line and in the classroom.

This paper describes ongoing research in the analysis of on-line peer-to-peer communication with the aim of developing methods to promote effective peer interaction in an intelligent CSCL system. The next section presents a model of effective collaborative learning interaction. Section 3 highlights the facet of the model focused on active learning conversation skills, and relates it to recent findings from an empirical collaborative learning study. Section 4 discusses future directions for this research.

2. A Model of Effective Collaborative Learning

Ideally, an Intelligent Collaborative Learning System (ICLS or I-CSCL) would be able to understand and interpret peer-to-peer conversation, and could actively support the group during their learning activities. Such a system, however, would need not only powerful natural language understanding capabilities, but also the knowledge required to advise, support, and guide the group toward maximum effectiveness. In working toward the realization of this vision, this research has focused on developing and implementing a model of collaborative interaction based heavily on psychological group learning support strategies; later the model may draw upon natural language understanding functionality. The model is designed to help an ICLS recognize and target group interaction problem areas. Once targeted, the system can take actions to help students collaborate more effectively with their peers, maximizing student and group learning.

The CL (Collaborative Learning) Model presented here identifies the characteristics exhibited by effective collaborative learning teams, and based on these characteristics, suggests strategies for promoting effective student interaction. The model is based on a review of research in educational psychology and computer-supported collaborative learning [2, 4, 6, 7, 8, 14, 15], and empirical data from a study in collaborative interaction and problem solving [12].

The characteristics studied and seen to be exhibited during effective collaborative learning interaction fall into five categories: participation, social grounding, active learning conversation skills, performance analysis and group processing, and promotive interaction. Table 1 describes, in brief[1], the characteristics exhibited by effective learning teams for each of the five facets.

Table 1. The five facets of the CL Model and their corresponding characteristics

CL Model Facet	Characteristics of Effective Learning Teams
Participation	- All the students actively participate in the group's discussions - Team members share their ideas openly
Social Grounding	- Students establish and maintain a shared understanding of the problem and proposed solutions
Active Learning Conversation Skills	- Team members encourage each other to justify their opinions, and articulate and explain their thinking
Performance Analysis and Group Processing	- Students individually and collectively assess their progress - The team as a whole reflects on its performance
Promotive Interaction	- Students verbally promote each other's understanding through support, help, and encouragement - Each student receives the help he needs from his peers

Perhaps the uniqueness of the CL Model lies in the artificial intelligence-based strategies it recommends for helping students attain the collaborative learning skills they need to excel in each of the five model categories. Table 2 summarizes these instructional strategies and their corresponding CL Model categories. The left hand column of Table 2 lists the five facets of the CL Model, and the top row of the table lists candidate components of an intelligent assistance module in an ICLS. Each strategy is listed across from the CL Model facet it strives to promote, and under the software component which might implement it. For example, the instructional planning component may be responsible for selecting roles to assign to students, and determining when group members should switch roles – a strategy designed to promote social grounding. Full explanations of the strategies can be found in [12].

While the CL Model characterizes the many diverse aspects of effective peer interaction, its focus is promoting Active Learning. The students who benefit most from collaborative learning situations are those who encourage each other to justify their opinions, and articulate and explain their thinking. Active Learning (AL) conversation

[1] A full explanation of the CL Model and its components can be found in [12].

skills, such as Encourage, Explain, Justify, and Elaborate, describe the core communication activities of effective learning groups. The Collaborative Learning Conversation (CLC) Skills Network, a speech act based hierarchy centered around the idea of Active Learning, provided the framework for analyzing the transcripts from the study mentioned earlier in this section. This coding scheme, shown in part by Figure 1, contains a minimal number of conversational acts in order to facilitate analysis and student usage, as discussed in section 3 (see [9] for an excellent description of a more elaborate scheme). The CLC Skills Network breaks down each CL skill category (Active Learning, Conversation, and Creative Conflict) into eight subskill categories (Request, Inform, Motivate, Argue, Mediate, Task, Maintenance, and Acknowledge). A full discussion of these subskill categories is outside the scope of this paper, however Table 3 offers a very brief description of each. The subskill categories contain sets of Attributes (such as Agree, Disagree, Explain, or Assert), each of which is assigned a sentence opener. The sentence openers represent characteristic sentence starters from the subskill categories to which they belong.

The next section takes a closer look at the facet of the CL Model concerned with Active Learning Conversation Skills. Data analysis from a study in collaborative dialogue during problem solving is presented, and this analysis motivates further work planned in this area.

Table 2. The CL Model support strategies that could be implemented by each ICLS component

	ICLS Component				
CL Model Facet	**CL Skill Coach**	**Instructional Planner**	**Student/ Group Model**	**Learning Companion**	**Personal Learning Assistant (PaL)**
Participation	Facilitate round-robin brainstorming sessions	Determine when to initiate round-robin brainstorming sessions			Encourage participation
Social Grounding		Choose roles to assign to students, and rotate roles at appropriate times		Fill in missing roles in group	Ensure students are playing their assigned roles
Active Learning Conversation Skills	Provide feedback/ coaching on conversation skill usage	Assign tasks that require Active Learning Skills	Evaluate student/ group Active Learning skill usage statistics	Play devil's advocate to encourage active learning skill utilization	
Performance Analysis & Group Processing	Provide feedback on group/ individual performance		Allow students to inspect and comment on their student/ group models		
Promotive Interaction	Ensure adequate elaboration is provided in explanations	Assign mentors or helpers to students	Update student/group models when students ask for and receive help		Alert students to their peers' requests for help

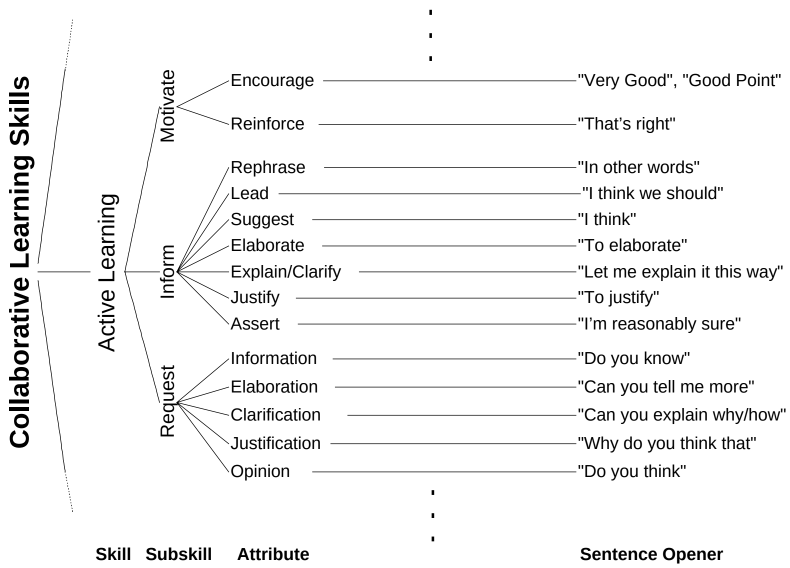

Figure 1. The Active Learning Skills section of the Collaborative Learning Conversation Skill Network (adapted from McManus and Aiken's Collaborative Skill Network, [8])

Table 3. Definitions of CL Conversation Skills and Subskills

CL Skill	Subskill	Description
Active Learning	**Request**	**:** Ask for help/advice in solving the problem, or in understanding a team-mates comment.
	Inform	**:** Direct or advance the conversation by providing information or advice.
	Motivate	**:** Provide positive feedback and reinforcement.
Conversation	**Task**	**:** Shift the current focus of the group to a new subtask or tool.
	Maintenance	**:** Support group cohesion and peer involvement.
	Acknowledge	**:** Inform peers that you read and/or appreciate their comments. Answer yes/no question.
Creative Conflict	**Argue**	**:** Reason (positively or negatively) about comments or suggestions made by team members.
	Mediate	**:** Recommend an instructor intervene to answer a question.

3. Supporting Collaborative Learning Conversation

The CL Model presented in the previous section describes the characteristics exhibited by effective collaborative learning teams, and suggests strategies for promoting effective peer interaction. An ICLS that can dynamically analyze peer-to-peer conversation and actions could identify a group's strengths and weaknesses, and determine which methods and strategies to apply in order to best further the group learning process. This section briefly describes the empirical evaluation of two collaborative learning tools that automate the analysis and understanding of collaborative learning interaction and activity, furthering the possibility of an ICLS which can support and enhance the group learning process. A full description of this study can be found in [13].

Sentence openers provide a natural way for users to identify the intention of their conversational contribution without fully understanding the significance of the underlying communicative acts [1, 8, 10]. Table 4 shows a dialogue, taken from our study, in which Rita[2] explains to Chris why the group needs to consider the number of playgrounds. The sentence openers are italicized. Rita explains that determining the number of playgrounds will

[2] The names of subjects have been changed to protect their privacy

help the group decide how to model the multiplicity of the relation between the school and its playground(s).

During the study, a structured, sentence opener-based communication interface (Figure 2) with a dynamic tagging and logging facility serves as the basis for interpreting the group conversation. The interface contains groups of sentence openers organized in categories that are easy to understand. The sentence openers and communication categories represent the Collaborative Learning Conversation (CLC) Skills Network, described in section 2. The structured interface logs student conversation at three increasingly specific levels in accordance with the skills, subskills, and attributes defined in the CLC Skills Network (see Figure 1 and Table 3).

Table 4. Rita helps Chris understand the concept of multiplicity

Student	Subskill	Attribute	Sentence
Rita	Inform	Suggest	*I think* schools have zero or 1 or 2 playgrounds, usually
Rita	Inform	Justify	*To justify* sometimes there is a separate playground for the youngest kids
Chris	Request	Justification	*Why* are we questioning the number of playgrounds?
Rita	Inform	Explain/Clarify	*Let me explain it this way* Chris -- we needed to make the multiplicity on the school/playground link

Figure 2. The CL Interface

3.1 A Case Study in Peer Interaction

In order to determine if adult learners would tolerate a sentence opener-based interface, and to test the correctness and completeness of the CLC Skills Network, we ran a study in which groups of subjects were asked to communicate through our sentence opener interface while solving object-oriented design problems using Object Modeling Technique (OMT) [11]. Five groups of three MITRE technical staff members each participated in the study over the course of a month. Following the specifications of OMT, each group collaboratively solved one design problem using a shared OMT Editor (Figure 3). An example of a design problem is shown below.

> *Exercise 1: Prepare a class diagram using the Object Modeling Technique (OMT) showing relationships among the following object classes: school, playground, classroom, book, cafeteria, desk, chair, ruler, student, teacher, door, swing. Show multiplicity balls in your diagrams.*

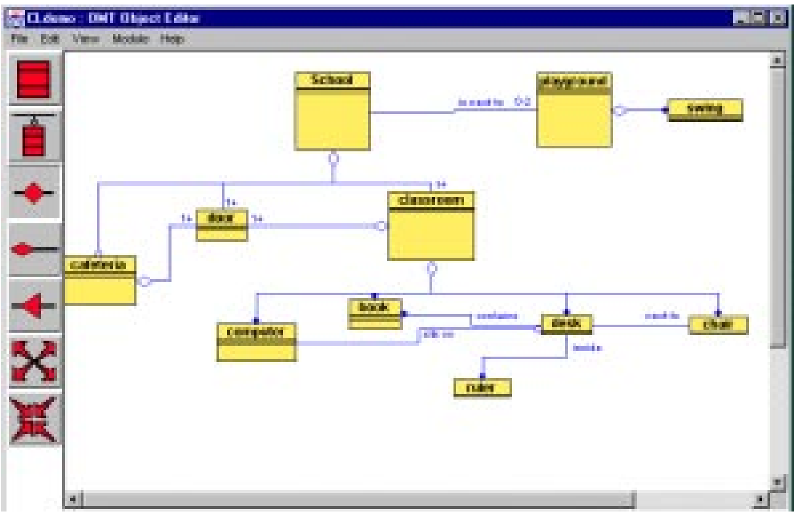

Figure 3. The shared OMT Editor

The group members communicated through the CL Interface (Figure 2), a sentence opener interface based on the CLC Skills Network. To contribute to the group conversation, a student selects a sentence opener from one of the eight subskill categories described in Table 3. The sentence opener appears in the chat box (the lower text window in Figure 2) where the student can type in the rest of the sentence. Students view the ongoing conversation in the large window above the text box displaying the students' names and utterances.

3.2 Results from the Case Study

This section summarizes, in part, the results of the collaborative learning study [13]. The five groups took from 1 to 1.5 hours to complete the design task described in section 3.1. The researchers observed the students as they worked through the exercise, and individually administered questionnaires afterwards. The questionnaires revealed that the subjects felt a high degree of engagement, but only a slight degree of control during the study. Almost all students had a few minor technical problems with the functionality of the OMT Editor. The subjects liked the chat-style interface, however most of these users were positively biased towards chat tools in general. Although some of the subjects found having to choose a sentence opener somewhat restrictive, most subjects became more comfortable with the interface once they had a chance to experiment with it.

The students were not given help or guidance during the problem solving phase. Some subjects expressed their desire for an on-line instructor, who could help to distribute roles and maintain group control during the problem solving activity. The next implementation of this software will include an intelligent collaborative learning coach, designed to promote effective group learning behavior. Activities such as distributing roles (such as facilitator, motivator, or questioner) to students [3], and assisting in maintaining group cohesion and control are candidates for the CL coach's focus.

Subjects rated their learning of OMT during the study on a scale from –3 (learned no OMT) to 3 (learned a lot of OMT). In general, those students who were already familiar with OMT from either a formal course or work experience (9/15) reported learning less OMT than those who did not already know OMT (6/15).

Analysis of the data from this study revealed that the students who spent considerable effort (more than 30% of their total contributions) participating in the conversation by acknowledging their peers' comments did not learn as much as the students who were actively engaged in the learning process, utilizing more Active Learning, Maintenance, Task and Argument conversation skills, and practicing less Acknowledgement. The horizontal axis of Figure 4 shows the students ordered according to their learning experiences, and describes each subject's degree of participation (with respect to his group members) and acknowledgement (as a percentage of his total contributions). The last five points on the graph show that the level of acknowledgment for the five students who felt they learned a considerable amount of OMT is significantly lower than their level of participation.

In all groups, the subjects' usage of Active Learning skills was roughly proportional to their degree of participation in the group conversation. For example, if Bill's contributions accounted for 30% of the total conversation, then Bill's Active Learning contributions accounted for roughly 30% of the total Active Learning skill usage for the group. The percentage of AL contributions a student made to the group, as a percentage of his total contributions, was slightly correlated with the degree to which that student felt he learned OMT. The first-time learners' percentage of AL Requests was highly correlated with the degree to which he felt he learned OMT. The students who asked more questions felt they learned more OMT during the study (Figure 5).

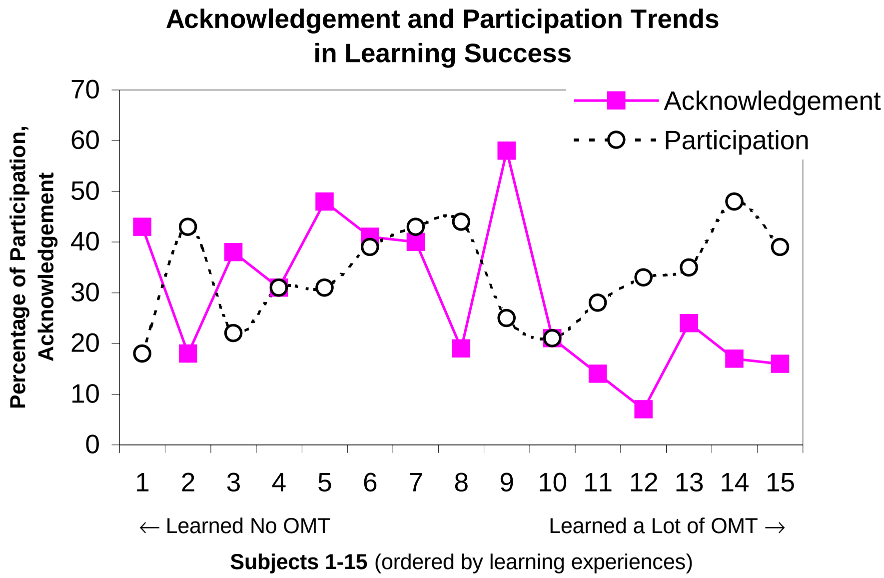

Figure 4. The students who participated more and acknowledged less felt they learned the most

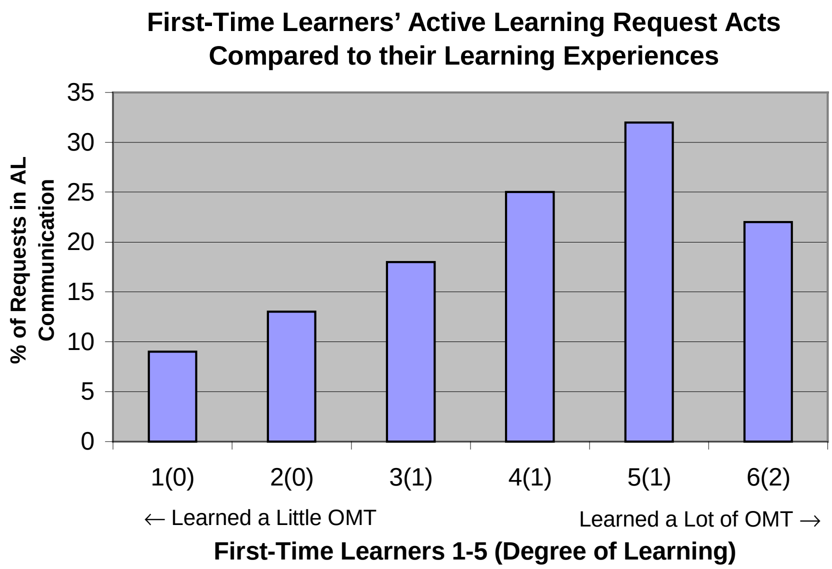

Figure 5. The first-time learners who ask more questions felt they learned more OMT

The number of questions asked by a student, however, should not be singly predictive of the degree to which a student has learned the subject matter. A student asking a question will learn only if the group responds to his request for help by providing a relevant, adequately elaborated, understandable response [15]. In general, the number of questions a student asks must be considered along with the quality and amount of support provided by his team members. In this study, most team members were very supportive of each other, and in many cases, students went out of their way to help their team members (e.g. Table 4).

3.3 A Closer Look at the Data

This section takes a closer look at two groups that participated in this study, and compares some telling characteristics of these groups. The students in one group were not as committed as those in another to helping their peers understand of the subject matter. This was evident in the transcripts, and telling in the summary of CL skills. Figure 5 illustrates summaries of the total percentages of CLC skills used by a very supportive group, and an unfocused group which was not as supportive of each other's learning, respectively. In Group A, acknowledgement accounted for only 13% of the conversation, while in Group B, acknowledgement accounted for 40% of the conversation. Results from all experiments in this study showed clearly that the percentage of the conversation comprised of acknowledgement provides clues about the quality of learning in the group. Students who felt they learned the most during the study were members of groups with lower acknowledgement activity (Figure 4, section 3.2).

The pie chart summarizing Group A's collaborative interaction shows a problem-solving conversation balanced by all the CLC skills. A closer look at this group shows group members participating evenly, with all students utilizing an almost equal number of Active Learning skills. These students also gave each other ample opportunity to draw on the shared OMT tool. This was an extremely balanced group in both conversation and student OMT tool control.

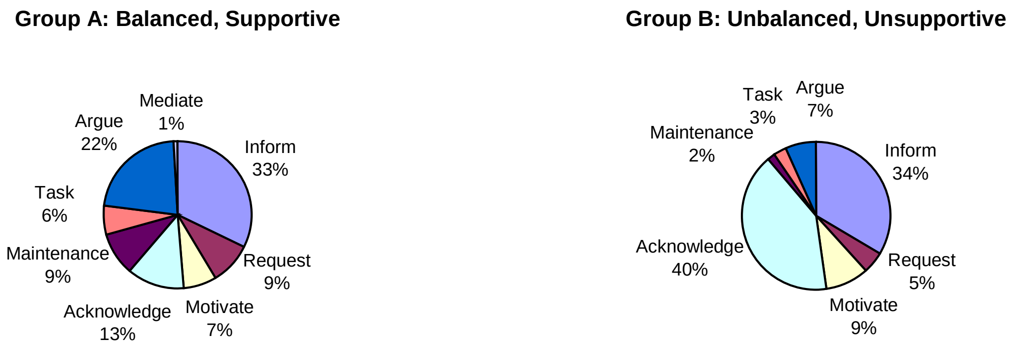

Figure 5. Summary of CL Conversation Skills for a very supportive group (Group A), and one which was not particularly supportive (Group B)

The pie chart summarizing Group B's collaborative interaction shows that Acknowledge and Inform contributions comprised 74% of the conversation. Very little group maintenance and task management activity occurred in Group B, compared to Group A. A closer examination of this group shows that the few questions group members did ask each other went unanswered. The student who participated in the conversation the least completed the group's OMT design almost exclusively on his own. This student had taken a formal course on OMT prior to the study, whereas the others students were not as experienced. Consequently, the first-time learner in this group did not feel that he learned OMT during the study.

Both Groups A and B produced comparable solutions to the problem. In collaborative learning activities, however, a team that produces a good solution to the problem does not necessarily satisfy the intended goal of helping all the team members learn the subject matter (and learning how to work together as a result [3]). The analysis presented in this section demonstrates that summaries of student communicative actions and actions on a shared workspace provide clues about the quality of learning in a group. Characterizing effective sequences of interactions between peers during the learning session will provide an even more convincing case that this level of knowledge is appropriate for enabling an ICLS to dynamically analyze group activity and support group interaction. This idea is elaborated upon in the following section on future work.

4. Discussion and Future Work

Learning with peers can enrich a student's learning experience, however the benefits of collaborative learning apply only to supportive learning teams composed of students who are committed to their peers' learning success. The CL Model described in this paper describes the characteristics exhibited by effective learning teams, namely participation, social grounding, performance analysis and group processing, application of active learning conversation skills, and promotive interaction. This model provides ICLS developers with a framework and set of recommendations for helping groups acquire effective collaborative learning skills.

The level of information provided by the CL Interface, along with knowledge of student actions on a shared workspace, provides insight into the group interaction as shown by the analysis presented in this paper. This knowledge appears to be sufficient for enabling an intelligent coach to observe and draw inferences about the learning group. The next step is to characterize sequences of student interaction which yield effective and ineffective group learning experiences. The analysis of these sequences applied to the structured foundation of the CL Model will guide the ICLS in further understanding the group interaction and determining how to best support the collaborative learning process. This understanding will also enable an intelligent coach or simulated peer [5] to intelligently participate in the group conversation.

References

[1] Baker, M. & Lund, K. (1996). Flexibly structuring the interaction in a CSCL environment. *Proceedings of the European Conference on Artificial Intelligence in Education (EuroAIED '96)*, 401-407.

[2] Brown, A. & Palincsar, A. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. Resnick (Ed.), Knowledge, learning and instruction (pp. 307-336), Lawrence Erlbaum Associates.

[3] Burton, M. (1998). Computer modelling of dialogue roles in collaborative learning activities. Unpublished doctoral dissertation, Computer Based Learning Unit, The University of Leeds.

[4] Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1995). The evolution of research on collaborative learning. In H. Spada and P. Reinmann (Eds.), *Learning in Humans and Machines*, Elsevier Science.

[5] Goodman, B., Soller, A., Linton, F., & Gaimari, R. (1998). Encouraging student reflection and articulation using a learning companion. *International Journal of Artificial Intelligence in Education*, 9(3-4), 237-255.

[6] Jarboe, S. (1996). Procedures for enhancing group decision making. In B. Hirokawa and M. Poole (Eds.), Communication and Group Decision Making (pp. 345-383). Thousand Oaks, CA: Sage Publications.

[7] Johnson, D., Johnson, R., & Holubec, E. J. (1990). *Circles of learning: Cooperation in the classroom* (3rd ed.). Edina, MN: Interaction Book Company.

[8] McManus, M. & Aiken, R. (1995). Monitoring computer-based problem solving. *Journal of Artificial Intelligence in Education*, 6(4), 307-336.

[9] Pilkington, R. (1997). *Analysing educational discourse: The DISCOUNT scheme.* (CBLU Technical Report No. 019703). The University of Leeds, Leeds, UK: Computer Based Learning Unit.

[10] Robertson, J., Good, J. & Pain, H. (1998). BetterBlether: The design and evaluation of a discussion tool for education. *International Journal of Artificial Intelligence in Education*, 9(3-4), 219-236.

[11] Rumbaugh, J., Blaha, M., Premerlani, W., Eddy, F., & Lorensen, W. (1991). *Object-Oriented modeling and design*. Englewood Cliffs, NJ: Prentice Hall.

[12] Soller, A., Goodman, B., Linton, F., & Gaimari, R. (1998). Promoting effective peer interaction in an intelligent collaborative learning system. *Proceedings of the 4th International Conference on Intelligent Tutoring Systems*, San Antonio, TX, 186-195.

[13] Soller, A., Linton, F., Goodman, B., Lesgold, A. (1999). Toward Intelligent Analysis and Support of Collaborative Learning Interaction. *Proceedings of the Ninth International Conference on Artificial Intelligence in Education*, LeMans, France. To appear.

[14] Teasley, S. & Roschelle, J. (1993). Constructing a joint problem space. In S. Lajoie & S. Derry (Eds.), Computers as cognitive tools (pp. 229-257). Hillsdale, NJ: Lawrence Erlbaum.

[15] Webb, N. (1992). Testing a theoretical model of student interaction and learning in small groups. In R. Hertz-Lazarowitz and N. Miller (Eds.), *Interaction in Cooperative Groups: The Theoretical Anatomy of Group Learning* (pp. 102-119). New York: Cambridge University Press.