# What Makes Peer Interaction Effective? Modeling Effective Communication in an Intelligent CSCL

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### Abstract

Placing students in a group and assigning them a task does not guarantee that the students will engage in effective collaborative learning behavior. 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. The model is designed to help an intelligent collaborative learning system recognize and target group interaction problem areas.

We describe the empirical evaluation of two collaborative learning tools that automate the analysis of peer 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. The results also suggest that structured, high-level knowledge of student conversation and activity appears to be sufficient for automating the assessment of group interaction, furthering the possibility of an intelligent collaborative learning system that can support and enhance the group learning process.

## 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 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 may 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. 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 analyzing on-line peer-to-peer communication with the aim of developing methods to promote effective peer interaction in an intelligent CSCL system. We begin by presenting a model of effective collaborative learning interaction. We then highlight the facet of the model focused on conversation skills, and relate it to recent findings from an empirical study. We conclude this paper by setting the stage for the next phase of this research.

## A Model of Effective Collaborative Learning

The Collaborative Learning (CL) Model identifies the characteristics exhibited by effective collaborative learning teams based on a review of research in educational psychology and computer-supported collaborative learning (Brown and Palincsar 1989; Jarboe 1996; Johnson, Johnson, and Holubec 1990; McManus and Aiken 1995; Webb 1992), and empirical data from a study conducted as part of this research (Soller et al. 1996). The study was conducted during a five day course in which students learned and used Object Modeling Technique (OMT)

(Rumbaugh et al. 1991) to collaboratively design software systems. The students worked in groups of four or five, and were videotaped using ceiling-mounted cameras. The videotape transcriptions were coded with a speech act based scheme (described later in this section), and studied through summary and sequential analysis techniques.

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. The following five subsections describe these categories, their corresponding characteristics, and the strategies an intelligent CSCL system could employ to help students attain the collaborative learning skills required to excel in each category. A full description of this model can be found in (Soller et al. 1998).

## Participation

A team's learning potential is maximized when all the students actively participate in the group's discussions. Building involvement in group discussions increases the amount of information available to the group, enhancing group decision making and improving the students' quality of thought during the learning process (Jarboe 1996). Encouraging active participation also increases the likelihood that all group members will learn the subject matter, and decreases the likelihood that only a few students will understand the material, leaving the others behind.

An intelligent CSCL system (ICSCL) can encourage participation by initiating and facilitating round-robin brainstorming sessions (Jarboe 1996) at appropriate times during learning activities. Consider the following scenario. An ICSCL presents an exercise to a group of students. After reading the problem description to himself or herself, each group member individually formulates procedures for going about solving the problem. A student who is confident that he has the "right" procedure may speak up and suggest his ideas, whereas the student who is unsure (but may actually have the best proposal) may remain quiet. During this phase of learning, it is key that all students bring their suggestions and ideas into the group discussion. The ICSCL initiates and facilitates a round-robin brainstorming session a few minutes after the students have read the problem description. Each student in the group is required to openly state his rationale for solving the problem while the other students listen. Round-robin brainstorming sessions establish an environment in which each student in turn has the opportunity to express himself openly without his teammates interrupting or evaluating his opinion. An ICSCL can help ensure active participation by engaging students in these sessions at appropriate times.

*Personal Learning Assistants* (PaLs), personified by animated computer agents, can be designed to "partner" with a student, building his confidence level and encouraging him to participate. Providing a private channel of communication (Koschmann et al. 1996) between a student and his personal learning assistant allows the student to openly discuss his ideas with his PaL without worrying about his peers' criticisms. A student's PaL could help him develop his ideas before he proposes them to the other students. The personal learning assistant may also ask the student questions in order to obtain a more accurate representation of his knowledge for input to the student model. A more accurate student model allows coaching to better meet student needs.

## Social Grounding

Teams with social grounding skills establish and maintain a shared understanding of meanings. The students take turns questioning, clarifying and rewording their peers' comments to ensure their own understanding of the team's interpretation of the problem and the proposed solutions. "In periods of successful collaborative activity, students' conversational turns build upon each other and the content contributes to the joint problem solving activity (Teasley and Roschelle 1993)."

Analysis of the data collected from our study (Soller et al. 1996) revealed that students in effective learning teams naturally take turns speaking by playing characteristic roles (Burton 1998) such as questioner, mediator, clarifier, facilitator, and motivator.

An ICSCL can model the turn-taking behavior that is characteristic of teams with effective social grounding skills by assigning the students roles, and rotating these roles around the group for each consecutive dialogue segment. The beginning of a new dialogue segment is identified by the start of a new context, often initiated by sentence starters such as, "OK, let's move on".

One or more critical roles, such as questioner or motivator, may be missing in a group if there are too few students to fill all the necessary roles. A missing role can be played by a simulated peer, or *learning companion* (Chan and Baskin 1988, Goodman et al. 1997). The learning companion can be dynamically adapted to best fit the needs of the group, playing the role of critic during one dialogue segment, and facilitator during the next.

## Active Learning Conversation Skills

An individual's learning achievement in a team can often be determined by the quality of his communication in the group discussions (Jarboe 1996). Skill in learning collaboratively means knowing when and how to question, inform, and motivate one's teammates, knowing how to mediate and facilitate conversation, and knowing how to deal with conflicting opinions.

The Collaborative Learning Conversation Skills Taxonomy[1] (shown in part by Figure 1) illustrates the conversation skills which are key to collaborative learning and problem solving, based on our studies (Soller et al.

[1] The structural basis for the CLC Skills Taxonomy was provided by McManus and Aiken's (1995) Collaborative Skills Network, which structures and extends the cooperative learning skills defined by Johnson and Johnson (1990).

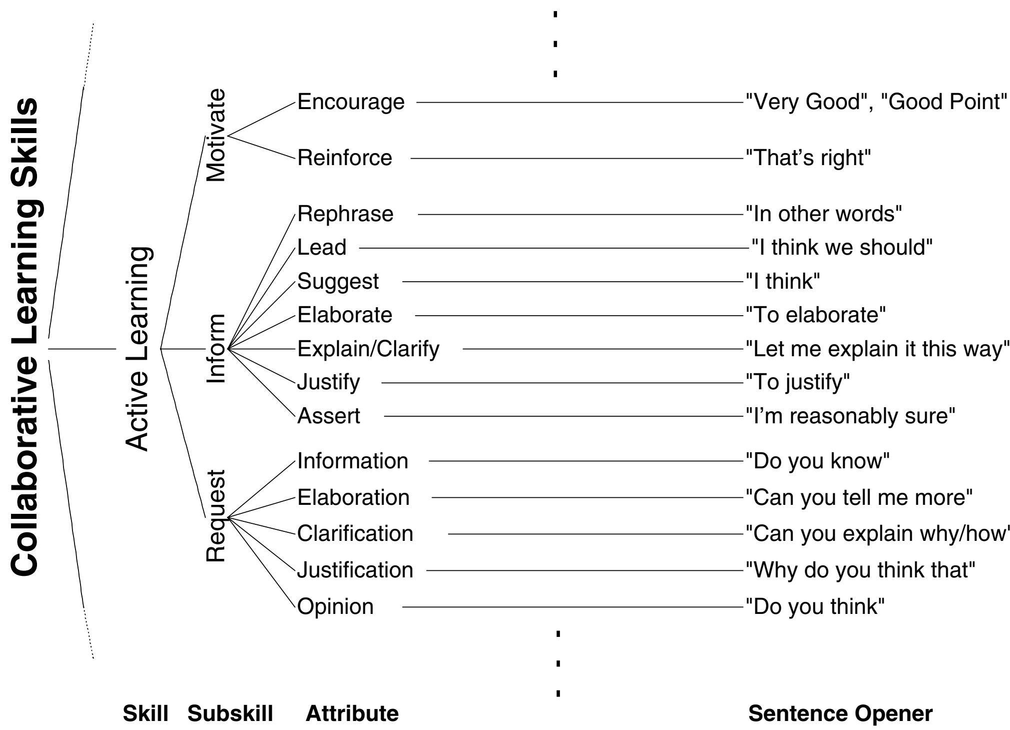



**Figure 1:** The Active Learning Skills section of the Collaborative Learning Conversation Skill Taxonomy (adapted from McManus and Aiken's Collaborative Skills Network, 1995)

1996; also see the next section). The taxonomy breaks down each learning conversation skill type (Active Learning, Conversation, and Creative Conflict) into its corresponding subskills (e.g. Request, Inform, Acknowledge), and attributes (e.g. Suggest, Rephrase). Each attribute is assigned a sentence opener which conveys the appropriate dialogue intention.

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 skills, such as Encourage, Explain, Justify, and Elaborate, describe the core communication activities of effective learning groups. The three subskill categories encompassing Active Learning are Inform, Request, and Motivate.

Students solving open-ended problems, in which an absolute answer or solution may not exist, must explain their viewpoints to their peers, and justify their opinions. Assigning students open-ended activities encourages them to practice these essential active learning conversation skills. A learning companion in an ICSCL can also encourage students to elaborate upon and justify their reasoning by playing the role of devil's advocate (Jarboe 1996).

## Performance Analysis and Group Processing

Group processing exists when groups discuss their progress, and decide what behaviors to continue or change (Johnson, Johnson, and Holubec 1990). Group processing can be facilitated by giving students the opportunity to individually and collectively assess their performance. During this self evaluation, each student learns individually how to collaborate more effectively with his teammates, and the group as a whole reflects on its performance.

An ICSCL can promote group processing by evaluating students' individual and group performance, and providing them with feedback. Students should receive individual evaluations in private, along with suggestions for improving their individual performance. The team should receive a group evaluation in public, along with suggestions for improving group performance. The purpose of providing a group evaluation is to inspire the students to openly discuss their effectiveness while they are learning and determine how to improve their performance. This introspective discussion may also be provoked by allowing the students to collaboratively view and make comments on their student and group models (Bull and Broady 1997).

## Promotive Interaction

A group achieves *promotive interdependence* when the students in the group perceive that their goals are positively correlated such that an individual can only attain his goal if his team members also attain their goals (Deutsch 1962). In collaborative learning, these goals correspond to each student's need to understand his team members' ideas, questions, explanations, and problem solutions.

Students who are influenced by promotive interdependence engage in *promotive interaction*; they verbally promote each other's understanding through support, help, and encouragement (Johnson, Johnson, and Holubec 1990). If a student does not understand the answer to a question or solution to a problem, his teammates make special accommodations to address his misunderstanding before the group moves on. Ensuring that each student receives the help he needs from his peers is key to promoting effective collaborative interaction.

Webb (1992) outlines five criteria for ensuring that students provide effective help to their peers in a collaborative environment. These criteria are (1) help is timely, (2) help is relevant to the student's need, (3) the correct amount of elaboration or detail is given, (4) the help is understood by the student, and (5) the student has an opportunity to apply the help in solving the problem (and uses it!). The following paragraphs suggest strategies to address each criteria.

When a student requests help, the ICSCL can encourage his teammates to respond in a timely manner. Assigning a mentor to each student provides them with a personal support system. Student mentors feel responsible to ensure their mentee's understanding, and mentees know where to get help when they need it.

In response to their questions, students must be provided with relevant explanations containing an adequate level of elaboration. Their peers, however, may not know how to compose high-quality, elaborated explanations, and may need special training in using examples, analogies, and multiple representations in their explanations (Blumenfeld et al. 1996). To increase the frequency and quality of explanations, and ICSCL could strategically assign students roles such as "Questioner" and "Explainer" to help them practice and improve these skills.

Webb's fourth and fifth criteria can be met by an ICSCL by analyzing a student's actions in conjunction with his communicative actions to determine whether or not a student understood and applied the help received.

### Summary of the CL Model

The CL Model identifies 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 ICSCL developers with a framework and set of recommendations for helping groups acquire effective collaborative learning skills. Table 1 summarizes the strategies that address each of the five CL Model categories, and shows how the ICSCL components can implement these strategies.

The left hand column of Table 1 lists the five facets of the CL Model, and the top row of the table lists candidate components of an intelligent assistance module in a CSCL system. The table summarizes the strategies discussed in this section for helping groups achieve effectiveness in each of the model's five categories, and lists each strategy under the software component which might implement it. For example, the coach may be responsible for facilitating round-robin brainstorming sessions in order to encourage participation; a learning companion may play the role of devil's advocate to prompt more active learning.

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.

| | **ICSCL 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** | Provide feedback on AL skill usage | Assign tasks that require students to practice AL Skills | Store student/ group AL skill usage statistics | Play devil's advocate to encourage active learning skill utilization | Encourage students to challenge or explain others' ideas |
| **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 | Help students compose high-quality, elaborated explanations | |

**Table 1:** The CL Model support strategies that could be implemented by each ICSCL component

## 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. The aim of this research is to provide an ICSCL with the knowledge and skills to determine how to promote effective student interaction in a group. An ICSCL 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 (from Table 1) in order to best further the group learning process. Developing a system to analyze peer-to-peer communication, however, is not a trivial task (Dillenbourg et al. 1995) since even the latest natural language understanding technologies today combined with CSCL tools are still limited in their ability to understand and interpret student communication. This section describes the empirical evaluation of two collaborative learning tools (CL Interface and shared OMT Editor) that automate the analysis of collaborative learning interaction and activity, furthering the possibility of an ICSCL that can support and enhance the students' learning. A full account of this study is in (Soller et al. 1999).

### A Case Study in Peer Learning Interaction

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. Table 2 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 help the group decide how to model the multiplicity of the relation between the school and its playground(s).

| **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 |

**Table 2:** Rita helps Chris understand the concept of multiplicity

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

In order to determine if adult learners would tolerate using sentence openers, and to test the correctness and completeness of the CLC Skills Taxonomy, we ran a second study. Groups of subjects were asked to communicate through a sentence opener-based chat interface (CL Interface, Figure 2) while solving object-oriented design problems using Object Modeling Technique (OMT) (Rumbaugh et al. 1991), the same object-oriented modeling and design methodology students used in the first study (Soller et al. 1996). The CL Interface is a structured, sentence opener-based communication interface (Baker and Lund 1996; Jermann and Schneider 1997; Robertson, Good, and Pain 1998) with a dynamic tagging and logging facility. It 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 Taxonomy (Figure 1). The structured interface logs student conversation at three increasingly specific levels in accordance with those defined in the CLC Skills Taxonomy. The highest level describes the skill categories: Active Learning, Conversation, and Creative Conflict. The next level delineates the eight subskill categories: Request, Inform, Motivate, Argue, Mediate, Task, Maintenance, and Acknowledge.

To contribute to the group conversation, a student selects a sentence opener from one of the subskill categories displayed on the lower half of the CL Interface (Figure 2). The sentence opener appears in the chat box (the lower text window), where the student can type in the rest of the sentence. Students view the group conversation as it progresses in the large window above the text box displaying the students' names and utterances. The sentence opener interface structures the group's conversation, making the students actively aware of the dialogue focus and discourse intent.

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 2). An example of a design problem is shown below.

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

Before each experiment, the students participated in a half hour interactive introductory lesson on OMT. During this session, the subjects also practiced using the CL Interface and OMT Editor, and learned how to access the tools' help facilities. The subjects were then assigned to separate rooms and networked computers to begin a design problem. During the problem solving session, the researchers observed quietly in the back of the subjects' rooms. Afterward, the students recounted their experience, and filled out questionnaires. The next two sections summarize the observations made and the data collected from the study to date.

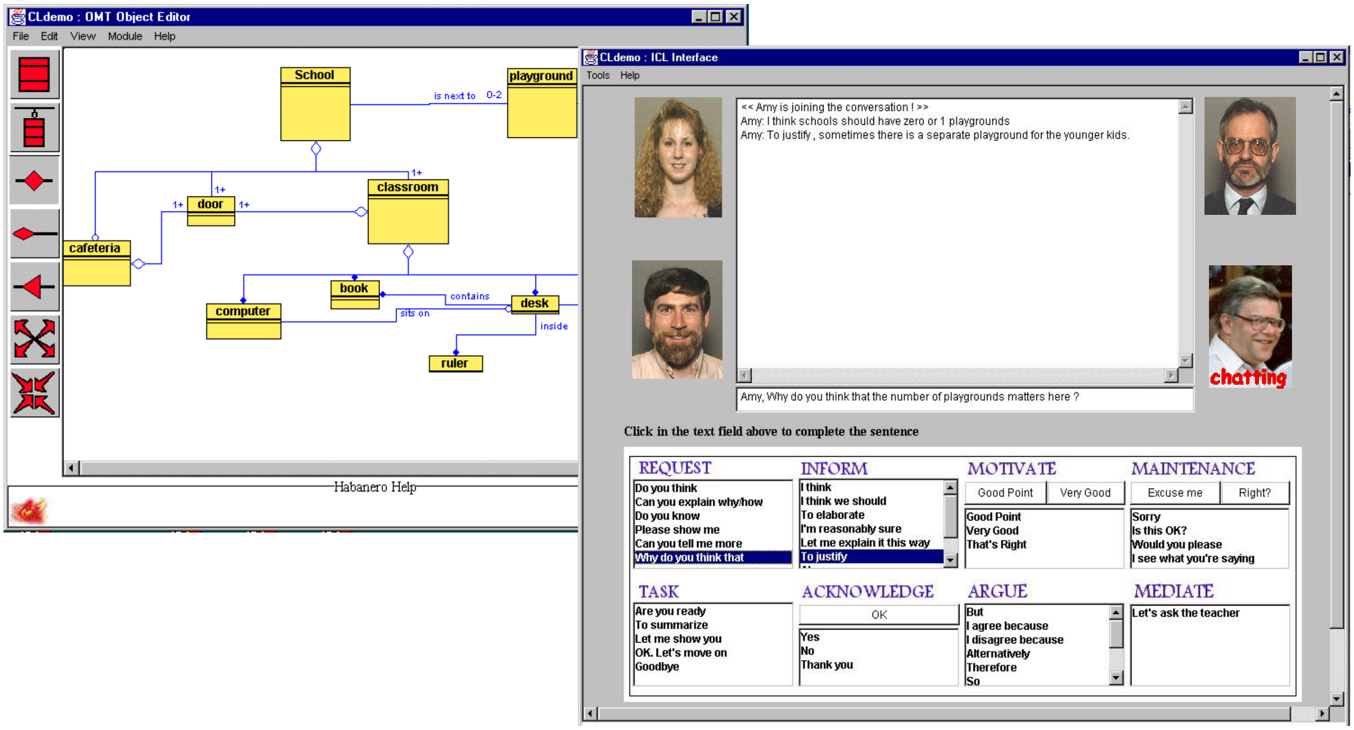



**Figure 2:** The Shared OMT Editor (left) and CL Interface (right)

## Results from the Case Study

The five groups took from 1 to 1.5 hours to complete the design task described in the previous section. The questionnaires revealed that the subjects felt a high degree of engagement, but only a slight degree of control during the study. 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.

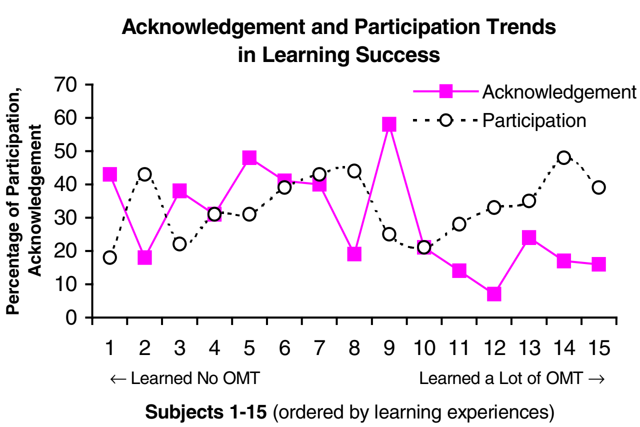
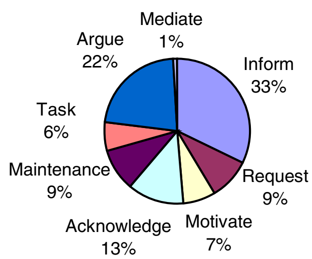



**Figure 3:** The students who participated more and acknowledged less felt they learned the most

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 (first-time learners) who did not already know OMT (6/15). No formal pre or post tests were administered. These subjects evaluate their own learning and determine what skills they need to improve every day as part of their jobs. For these subjects, self-assessing their learning during this study is akin to the self-assessment they perform regularly at work.

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 Argue conversation skills, and practicing less Acknowledgement. As shown in Figure 3, the level of acknowledgment for the five students who felt they learned a considerable amount of OMT (last five bars on graph) is significantly lower than their level of participation.

In all groups, the subjects' usage of Active Learning (AL) skills was roughly proportional to their degree of participation in the group conversation. 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



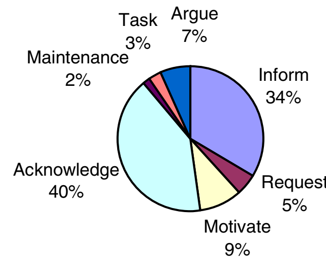




**Figure 4:** Summary of CL Conversation Skills for a very supportive group (Group A), and one which was not particularly supportive (Group B)

Requests was highly correlated with the degree to which they felt they learned OMT. Those that asked more questions felt they learned more during the study. This result is suggestive, but not statistically significant, due to the small number of first time learners participating in the study.

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 material. 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 (Webb 1992). 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.

## 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 them. The students in one group were not as committed as those in another to helping their peers understand the subject matter. This was evident in the transcript, and revealing in the summary of CLC skills. Figure 4 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 (also see Figure 3).

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 tool control.

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 revealed 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 much 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) (Burton 1998). 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 ICSCL to dynamically analyze group activity and support group interaction.

## Discussion and Future Work

Placing students in a group and assigning them a task does not guarantee that the students will engage in effective collaborative learning behavior. The CL 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. The model is designed to help an ICSCL recognize and target group interaction problem areas. Once targeted, the system can take actions to help students collaborate more effectively with their peers, maximizing individual student and group learning.

Selecting the proper strategies to apply to best further the group learning process requires an ICSCL to dynamically analyze peer-to-peer conversation and actions. 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 collaborative 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 ICSCL in further understanding the group interaction and determining how to best support the group during the learning process.

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