Session 2630

Dynamics of Peer Interactions in Cooperative Learning

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Abstract

Although many recent studies demonstrate that cooperative learning provides a variety of educational advantages over more traditional instructional models, little is known about the interactional dynamics among students in engineering workgroups. We explored these dynamics and their implications for engineering education by analyzing work sessions of student groups in a sophomore-level chemical engineering course at North Carolina State University. Using conversation analysis as a methodology for understanding how students taught and learned from one another, we found that group members engaged in two types of teaching-learning interactions. In the first type, *transfer-of-knowledge* (*TK*) sequences, students took on distinct teacher and pupil roles, and in the second, *collaborative sequences* (*CS*), they worked on problems with no clear role differentiation. Student management of both types of sequences was affected by gender factors and interpersonal communication. Our findings suggest that facilitating effective interactional dynamics can enhance cooperative learning in groups.

I. Introduction

In cooperative learning models, students are generally encouraged to work in groups both in and out of class. Both instructors and students report that structured cooperative learning improves students' understanding of course material as well as their communication and teamwork skills.[1,2,3] The use of cooperative learning has specifically been advocated as a means of retaining women in engineering programs, since women tend to prefer collaborative to individual and/or competitive learning. Strongly positive results have been reported for women working in collaborative teams,[3,4] although gender bias in such teams can diminish their effectiveness.[5]

Despite the acknowledged benefits of cooperative learning in engineering education, not much is understood about the interactional group dynamics that may lead to the success or failure of group efforts. For example, how does group interaction help students master both content and application of engineering concepts? How exactly is peer teaching and learning accomplished in these groups? And how do social factors such as gender and interpersonal relationships influence teaching and learning in groups?

In this study, we analyzed interactions among groups in the introductory chemical engineering course (material and energy balances). This paper reports principal findings of the study and suggests their implications for engineering education.

II. Study Design

Qualitative research methods can often be a useful means for investigating social and cultural issues in engineering.[5,6] One way questions about interactional dynamics can be approached is through an examination of dialogue. More specifically, the framework for this investigation is conversation analysis, which concentrates on how people use dialogue as they communicate with one another and organize joint action in their everyday lives.[7] Communication, linguistics, and sociology scholars have studied dialogue in telephone calls,[8] business meetings,[9] groups of children playing,[10] married couples' discussions,[11] and many other situations to determine how it constructs and expresses social relations and actions. Conversation analysis thus provides a helpful instrument for investigating how students use dialogue in their workgroups to perform joint activities, achieve communal goals, and manage social interactions.

Certain analysts have focused on how asymmetries between conversational participants are managed in dialogue. Differences in terms of knowledge, power, social status, situational role, gender, interpretive frameworks, and other social factors are present in most if not all conversations, and these asymmetries significantly influence dialogue and its development. Conversely, dialogic interaction may itself create and sustain asymmetries in power and status, which conversational participants must negotiate together.

Knowledge asymmetry is particularly relevant to this investigation, since cooperative learning involves the gaining, sharing and exchange of expertise among students. Knowledge asymmetries usually manifest themselves in dialogue when one participant is more expert than another with respect to the conversational topic and/or the situational task.[12] Such asymmetries affect the form, organization, and progress of dialogue.[13] When conversational participants perceive asymmetries in relevant knowledge, for instance, they frequently approach these asymmetries as obstacles to be removed in order to create and/or restore mutual understanding. Asymmetries in knowledge can thus precipitate a specialized form of dialogue that conversation analysts have called *teaching sequences*,[14] in which one conversational participant undertakes to instruct another concerning some topic of relevance to the situation at hand.

We used the concept of the teaching sequence as an analytic tool for exploring how cooperative learning is accomplished in student engineering groups. We would expect that in such groups, students would take on (and be permitted by others to take on) teacher and student roles in dialogue according to the particular distribution of knowledge and technical expertise in the group. We sought to determine how engineering student groups managed teaching sequences as they accomplished their work together, and how gender and interpersonal factors shaped and were shaped by teaching sequences.

The dialogue we analyzed was collected from four student groups enrolled in "Chemical Process Principles," the introductory chemical engineering course at North Carolina State University. The professor for this course, a long-time practitioner of cooperative learning**,** incorporates group work into each class period and also has students work in groups to complete weekly homework assignments. The homework groups are composed of 3-4 students and are formed by the instructor. As a rule, students remain in the same homework groups for the semester and meet twice or more each week. Additional details about the cooperative learning model implemented in the course and the instructional outcomes that derive from it are given by Felder et al.[15,16]

During the 1997 fall semester, we audio- and video- recorded the dialogue of four groups of varying gender composition (herein referred to as Groups A, B, C, and D) as they worked on assigned group homework problems. At the beginning of the semester, we approached candidate teams and told them of the purpose of the research and its methods (i.e., audio- and video-taping). Informed consent agreements were obtained from participating students; to protect confidentiality, pseudonyms rather than real names are used to refer to the students in this report.

For the portion of our research presented in this paper, we analyzed transcripts of one audio-recorded problem-solving session from each group, with the objective of understanding the interactional dynamics of teaching and learning as it occurred in the groups. Using prior research on teaching sequences as a benchmark, we identified all of the teaching sequences in each of the transcripts and examined how students managed the sequences. Since an important research goal for our project was to examine gender effects on the management of teaching and learning in groups, we also considered the relationship between group gender mix and teaching sequence management. Finally, we analyzed how interpersonal factors affected teaching sequences.

III. Types of Teaching Sequences

We found that students engaged in two qualitatively different types of teaching sequences in their group meetings: *transfer-of knowledge sequences (TK)* and *collaborative sequences (CS)*. TK sequences followed the typical dialogic pattern for teaching sequences described by Keppler and Luckmann,[14] but CS sequences did not.

In TKs, a student with greater expertise than one or more of the other students took on the role of teacher, conveying knowledge to one or more of the other group members, who acted as pupils. In the TK in Figure 1, for example, John asks a question, providing an opportunity for Stan to take on the role of teacher. Stan begins explaining how to do the problem to John, who acquiesces to Stan's authority as teacher and takes on the role of pupil.

Figure 1 Transfer-of Knowledge (TK) Teaching Sequence

77. John: Can I see what you did? [Note: John is asking to see the paper on which Stan has worked the problem. He is also showing Stan his own paper, on which he has attempted to work the problem]

78. Stan: It's useless doing that. All you need to do is multiply the moles times the um kilojoules per mole, like 100 times 19.36 because if you change it into kilograms, then you change the kilojoules per mole into kilogram...kilojoules per kilogram, you're just basically getting kilojoules. That's the same thing...

79. John: Ahhh...so what'd you do?

80. Stan: I did it. I did it all out. Um, I just changed 100 moles...to, uh, kilograms going in, see three eighths..

81. John: Oh, OK, OK.

82. Stan: Then I did the 100 mole to kilogram ratio.

83. John: But isn't it, isn't it in kilojoules per mole? To start with?

84. Stan: That's why you say 100, you say 19.36 kilojoules per mole and then you, times 100 moles and then how many kilograms are in that 100 moles.

85. John: Oh.

(Group A, 11/18/97, Teaching Sequence 2, TK, lines 77-86)

Pupils frequently initiate teaching sequences by asking a question,[14] as does John when he asks Stan if he can see his paper (line 77). By asking to see Stan's work, John signals his willingness to allow Stan to teach him; John's pupil role at this point is still tenuous, however, dependent on whether or not what he sees or hears from Stan seems helpful to him. Stan confidently assumes the role of teacher in line 78, passing judgment on John's approach as "useless" and explicitly describing how he himself has approached the problem. In lines 79, 81, and 83, we see John acquiescing to Stan's teacher role: he uses his speaking turns in the dialogue either to affirm Stan's statements or to ask Stan for more information, but not to initiate new topics.

In contrast to TKs, collaborative teaching sequences (CSs) were not marked by clear differentiation of group members into teacher and pupil roles. In the CS in Figure 2, for example, no one individual takes control of the dialogue, and no single teacher or pupil emerges. (Note: slash lines indicate simultaneous speech.)

Figure 2 Collaborative Teaching Sequence (CS)

139. Susan: Does it ask for, like, a specific unit we need to put it in?

140. Tiffany: Umhmm.

141. Susan: We can just do kilograms per liter?

142. Tiffany: Is that right?

143. (9-second pause)

144. Margaret: Did you get one point two oh oh two?

145. Tiffany: Yeah.

146. Margaret: Kilograms...and then change that to grams I guess.

147. Tiffany: Probably don't have to, um, what is it-is it kilograms per meters cubed or something like that? (For /the?) density/.

148. Susan: /Well.../

149. Tiffany: Yeah, the kilograms-

150. Susan: /Well/...   /grams/.

151. Margaret: /I know/ it's /grams/ per centimeter.

152. Tiffany: Yeah grams, kilograms per meter /cubed/.

153. Susan: /Kilograms/=

154. Margaret: /So it'd be meter, it'd be one above-/

155. Susan: /=would be (indeterminable)/ grams per centimeter cubed.

156. Tiffany: Kilograms per meter /cubed/?

157. Margaret: /How/ is that then? Okay, grams per centimeter, that's two below, you know, and then like kilograms is per meter?

158. Susan: Uhmm, kilograms per meter cubed.

(Group B, 12/4/97, Teaching Sequence 5, CS, lines 139-158)

In the CS in Figure 2, no one teacher or pupil can be identified. Susan begins with a question, which as we have seen in the sample TK, can signal a willingness to take on a pupil role in the dialogue. Tiffany, however, rather than taking on the role of teacher by responding with an explanation about what units to use for the answer and why, simply acknowledges that the problem being worked does indeed call for certain units. Susan then queries Tiffany, again providing an opportunity for Tiffany to respond as a teacher would, but Tiffany simply responds with a query of her own. Margaret, seemingly working on the same problem, then chimes in to check her answer with the others and makes her own suggestion regarding units. In the rest of the excerpt, members, speaking simultaneously, consider possibilities concerning the appropriate units to use for the answer. Throughout the sequence, the students appear to be working out the problem together *in situ* rather than anyone having solved the problem in advance.

IV. Gender and Teaching Sequence Types

TKs predominated over CSs in the transcripts we examined; of 54 total teaching sequences, 37 (69%) were TKs and 17 (31%) were CSs. Table 1 shows the breakdown of teaching sequence type by group: gender mix for each group is indicated.

Table 1 Teaching Sequences by Type and Group

Sequence Types	**Gp. A (3 males)**	**Gp. B (4 females)**	**Gp. C (2 females, 1 male)**	**Gp. D (2 males, 2 females)**
TK	8 (73%)	6 (50%)	13 (87%)	10 (62%)
CS	3 (27%)	6 (50%)	2 (13%)	6 (38%)
Total, Both Types	11	12	15	16

As can be seen in the table, TKs predominated over CSs in all groups except Group B, the all-female group, which had an equal number of TK and collaborative sequences (50% of each). Group D, which was mixed-gender but also gender-symmetrical, approached the all-female group in frequency of collaborative sequences (38% CSs). Interestingly, the next largest number of CSs occurred in the all-male group (27% CSs), with the lowest percentage of CSs (13%) occurring in Group C, the only gender-asymmetrical group.

The relative distribution of TKs versus CSs in the groups suggests that the gender mix of a group may play some role in the style of teaching sequences that occur in the group. The fact that the all-female group engaged in the highest percentage of collaborative sequences is consistent with other sociolinguistic research on gender and language indicating that women prefer collaborative floors (in which speaker turns overlap and participants contribute simultaneously to the ongoing interaction) to competitive floors (in which turns are taken one-at-a-time with participants competing for turns).[17] The greater number of CSs in the all-female group is also consistent with the research on gender and education cited in the introductory section.

Curiously, however, the simple presence or even majority of females in a group did not necessarily mean that the group would have a greater tendency to engage in collaborative sequences. Rather, the symmetry or asymmetry of gender mix in the groups also seemed to affect relative engagement in CSs vs. TKs. The 2-female, 2-male group, a symmetrical gender mix that included females, had the next highest percentage of collaborative sequences after the all-female group. However, that group was followed not by the two-female, one male group, as might be expected if the presence of women were the only factor affecting frequency of collaborative sequences, but by the all-male group, another symmetrical gender mix. The group with the most gender asymmetry, though it included a majority of females, in fact engaged in the fewest collaborative sequences. This pattern may be idiosyncratic to the groups we studied, given our small sample size. It is also possible, however, that gender asymmetry in groups (whether the minority gender is male or female) may increase the chances of asymmetrical interaction (TKs) rather than collaborative interaction (CSs).

The hypothesis that gender and gender mix influence the preferred modes of teaching and learning in a group is further supported by our analysis of the numbers of speaker turns in TKs vs. CSs. On average, CSs contained more participant turns per sequence than TKs, as shown in Table 2; however, the much higher average number of turns per CS sequence in the two single-gender groups (all male and all female) disproportionately raises the average number of turns per CS sequence for all groups combined. As can be seen in Table 2, the average number of turns per CS sequence in Groups C and D, the mixed-gender groups, does not appear to be much different from the average number of turns per TK sequence, suggesting that the single-gender groups were better able to sustain collaborative teaching sequences than the mixed-gender groups. Maintenance of CSs requires that participants refrain from competitive bids for the role of teacher, sustaining symmetrical rather than hierarchical relationships in the dialogue. The presence of members of the opposite gender in a group may make participants more competitive and less able to sustain the symmetrical role status typical of collaborative sequences. Data from a larger number of groups is needed, however, before the relationship between gender mix and teaching sequence preferences can be fully clarified.

Table 2 Average Number of Turns per Sequence for TKs and CSs

Group	Average Number of Turns for TKs	Average Number of Turns for CSs
A (3 males)	18.9	48.6
B (4 females)	16	132.1
C (2 females, 1 male)	21.1	17
D (2 males, 2 females)	22	23.4
All Groups	19.5	55.3

V. Interpersonal Behaviors in Teaching Sequences

Past research on teaching sequences has focused on how people move into and out of teacher and pupil roles during naturally occurring conversation, in which no pre-set goal drives the discourse.[14] In engineering groups, however, students have specific tasks to accomplish; and their management of boundaries between on-task and off-task interactions can make a difference to their progress. Sometimes, for instance, students may have to negotiate differences in opinion about which type of interaction is appropriate at a given time. In Figure 3, for example, Sarah makes a move to get her group working on the problems, but Colleen clearly wishes to continue in off-task socializing until missing group members have arrived:

Figure 3 Off-Task vs. On-Task Negotiation

69. Linda: That's comfort food.

70. Colleen: Yeah, it's bad for you but it's good.

71. Linda: Yeah really (laughing) high in fat,/ high in cholesterol/

72. Colleen: /I know, it's like it's/ a wonder that I don't weigh twice as much as I do.

73. Linda: (laughs)

74. (5-second pause and shuffling of papers)

75. Sarah: Well….

76. Colleen: And like I know it's like 8:25 but –

77. Sarah: Yeeah.

78. Colleen: I don't feel like working since nobody else is here.

(Group D, 12/1/97, lines 69-78)

Additionally, the ways students manage off-task versus on-task interactions appears to differ depending on the dominant mode of teaching sequence used by the group. In groups where TK sequences predominated, a clear separation between off-task and on-task interactions tended to be present. For instance, in group C, which had the highest percentage of TK sequences, 15 of 17 interpersonal interactions were external to the actual teaching sequences. These interpersonal interactions tended to constitute a form of socializing (e.g., what students did over the weekend, their plans for the evening, the next day, and so on). In Group B, by contrast, which had the highest percentage of collaborative sequences, interpersonal interactions were generally embedded within the teaching sequences and were somehow, if only tangentially, related to the problem at hand. Group B participated in very little truly off-task discourse. Its members did engage in interpersonal interactions; however, they commented on things like the professor's or their own work expectations and idiosyncrasies rather than talking about details of their personal lives. Of Group B's 10 interpersonal interactions, all but 3 were embedded within teaching sequences; of the three exceptions, one interpersonal interaction began the group meeting and one ended it.

We also discovered that group members sometimes used off-task interpersonal exchanges to manage symmetry and asymmetry in the conversation. On the one hand, off-task interactions could serve to re-assert symmetry in the dialogue. This was a strategy particularly useful to group members who spent more time as pupils than as teachers: it appeared to allow them to exercise emotional dominance in an interpersonal arena to counterbalance their subordination in teaching sequences. In Group C, for instance, one member, Marie, never successfully took on the role of teacher in the session we analyzed; however, she would sometimes employ humor in interpersonal interactions to re-insert herself as a participant of value in the group. In Figure 4, for example, her jokes about "flakiness" bring the group's attention to herself in a long teaching sequence otherwise dominated by Karen.

Figure 4 Use of Off-Task Interactions (Humor) to Re-assert Symmetry

370. Marie: Chunks of scale [floating?].
371. Karen: (Laughs) That is a good possibility, I mean, you know.
372. Marie: Which side is the scale building up on? Both sides /of it?/
373. Karen: /Well, no/ the scale is building up, is, like, the water vapor coming in could be impure, I mean think about all the stuff that's in the water that we drink. All the stuff that they put in there. You know, all the calcium and everything else, you know how stuff builds up on your pipes?
374. Marie: Yeah.
375. Karen: Probably the same type of thing happening on that pipe that exchanges the heat and it could end up flaking off into there. And /ending up out of the…/
376. Marie: /Flakey, I like that./
377. Karen: (Laughs) And um…
378. Marie: Chunks flake off.
379. Karen: (Laughs) And going into the water outlet stream, /so..

(Group C, 11/18/97, lines 370-379)

On the other hand, off-task interpersonal exchanges sometimes served to reinforce differential role and power positions in the groups. This was particularly the case in group D, where one member frequently tried to transfer conversational dominance in off-task interpersonal exchanges to conversational dominance in teaching sequences. In the excerpt in Figure 5, Sarah, having just dominated an off-task discussion about a recent exam (not included in the figure), assumes the management of task assignments in the group. Though Gavin at first goes along, asking which problem he should work on, he later reasserts autonomy by making his own choice (problem 2). Sarah consents, but is also quick to point out that she is already working on problem 2 and has completed problem 1 successfully. This particular incident, which might seem innocuous in isolation, is one of many like it: Sarah and Gavin "sparred" for authority and prominence in a similar manner throughout the meeting.

Figure 5 Use of Off-Task Interaction to Assert Asymmetry

345. Gavin: Which one for me?
346. Sarah: Um, why don't you, I don't know, she's doing three, which one are you?
347. Peter: Eh, I can start on any of 'em I guess.
348. Sarah: /If you/
349. Gavin: /I'll do two…/
350. Sarah: Okay, yeah I'm working on two also. Said I got one, I got the answer in the back of the book, if you wanna check it you're welcome to.

(Group D, 12/1/97, lines 345-350)

VI. Maximizing Benefits of Cooperative Learning

Both modes of group learning (TKs and CSs) can assist students in understanding and applying engineering concepts. Gender factors and interpersonal behaviors, however, appear to influence students' management of teaching sequences considerably--and, by implication, the educational effectiveness of group work. In this section, we consider what our findings suggest about facilitating a desirable cooperative learning experiences for students.

First, there is no way to avoid the asymmetries in knowledge and ability among group members that give rise to many of the problems, and even if there were a way, avoiding the asymmetries would not necessarily be desirable. Knowledge asymmetries are frequently the very factor that sparks cooperative teaching and learning in the group, and standard references on cooperative learning advise instructors to form teams that are heterogeneous in ability.[1] What the instructor *can* do is alert students to the nature of peer teaching and learning in groups and equip them with tools to deal with troublesome situations that might arise. Several specific suggestions follow.

- *Make group work worthwhile.* Group work imposes significant and unfamiliar time demands on students: time spent attending meetings and explaining things to teammates, time that students perceive might be better spent doing almost anything else. Good students in particular are justifiably frustrated when they could just as easily solve the assigned problems on their own. Group problem assignments, therefore, should be made challenging enough that the combined expertise of group members is required to complete them.
- *Help students to avoid interactional problems by educating them about the two types of teaching sequences.* Briefly describe the two modes of teaching and learning interactions in group work (transfer-of-knowledge sequences and collaborative sequences). A student who prefers TK-type sequences may be frustrated, for instance, if a teammate inclined toward CS dialogues does not respond to a question by taking on the role of teacher. Similarly, a student with a leaning toward CS dialogues may feel that a teammate with a TK preference either is taking an overly dominant role in the group (if the teammate always assumes the teacher role) or is not pulling his/her own weight (if the teammate habitually elects the pupil role).

Introducing students to some of the differences between the two modes of group learning empowers them to make conscious choices in the ways they work together.

- *Make students aware that some approaches to problem-solving are more appropriate than others when doing group wor*k. Studies of group decision-making suggest that the collaborative mode of CSs is likely to be most useful for complex problems that have many parts or steps involved, making the diversity of expertise afforded by the group an advantage in solving the problem.[18] Simpler problems, on the other hand, tend to be better and more efficiently solved individually rather than in a group, with subsequent knowledge transfer occurring most efficiently in TK sequences.
- *Explain to students that teacher-pupil roles are flexible in healthy groups, with students alternating between the roles*. Students sometimes gravitate toward either a teacher or a pupil role in their groups, which can foster power imbalances among group members and create a feeling that some group members are doing more than their share of the work. A useful strategy for preventing role-playing imbalances is for students to take responsibility for preparing and presenting different parts of the assignment, setting up the expectation that each member will come to meetings prepared to serve as the teacher on the particular part he or she has previewed. It may also be helpful occasionally to vary the usual structure of TK sequences. When students who tend to be habitual pupils ask questions, other group members, rather than jumping in to teach, could first ask them to explain how they are going about solving the problem. Habitual pupils are thus encouraged to articulate and explain what they *do* understand about the problem, which is likely both to strengthen their understanding and accustom them to contributing ideas. (Other members of the group, of course, would need to guide the pupil's work on the problem appropriately.)
- *Consider possible effects of asymmetrical population mixes in groups*. Several studies of cooperative learning indicate that setting up engineering groups to include only one female jeopardizes the female's chances of a full participatory role in the group.[2,6,19,20] The highly limited data in our study suggest that the opposite scenario (only one male) may also be problematic. Asymmetrical gender (and conceivably, ethnic) mixes may tend to make it more difficult for students to initiate and sustain CSs, even when the CS tends to be the better option for solving the types of problems at hand. More research with a greater number of groups could shed light on this matter.
- *Give students tips on how to approach group work efficiently*. Suggest that they pre-work the relatively straightforward parts of their assignments before their group meeting and then use TK sequences to clarify differences in the ways they have approached the problems. Further suggest that they go as far as they can to outline solutions to the more complex problems ahead of time, leaving the details of the calculations for the group meeting. This procedure is particularly beneficial to the habitual pupils in the group, who would otherwise leave it to the teachers to do most of the work in the group sessions, putting themselves in dire jeopardy in subsequent individual examinations.
- *Help students to (1) understand that groups engage in various types of interpersonal interactions and (2) recognize when such interactions are helpful and when they are not.* It is important for group members to recognize that they each have many potential areas of interpersonal power and to focus on using these areas to aid rather than hinder group progress. For instance, using humor to reassert symmetry is good if it helps the group to

coalesce and move towards completion of a task. It's less useful if it is employed to make fun of or distract other participants.

VII. Conclusion

Cooperative learning in engineering education has been shown to be effective at achieving a wide range of positive outcomes related to quality of learning and skill development, attitudes toward the educational experience, and self-confidence.[1,16] This study of interactional dynamics of student workgroups adds to our understanding of the effectiveness of cooperative learning for most students and suggests how gender and interpersonal factors influence teaching and learning in groups. Using well-established sociolinguistic methods of dialogue analysis, we have identified two interaction modes in peer teaching and learning within cooperative learning workgroups in a sophomore engineering course. In the first mode, *transfer-of-knowledge sequences* (*TKs*), students take the roles of teacher and pupil, and in the second mode, *collaborative sequences* (*CSs*), no such role differentiation exists. Our analysis of how students manage both modes suggests specific practical ideas for enhancing group work. Further work needs to be done, however, to fully understand how teaching/learning sequences in groups affect and are affected by interpersonal interactions, gender, and ethnicity distributions in workgroups. The methodology described in this article provides a powerful vehicle for continuing investigation of these issues.

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