Chapter 10
Knowledge Building Discourse in Peer-Led Team Learning (PLTL) Groups in First-Year General Chemistry

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Introduction

Although we know that cooperative techniques enhance student learning in PLTL, and more broadly in undergraduate chemistry courses, previous studies (reviewed in the corresponding dataset description chapter) have not investigated the interactional mechanisms that account for students' improved academic performance from cooperative learning in General Chemistry. In (Brown, Sawyer, & Frey, 2010), we examined the influence of peer-leader discourse in PLTL in General Chemistry. We showed that a peer leader's interactional style (whether instructional or facilitative) influenced student discussions. When a peer leader's interactional style was almost entirely facilitative, the students' discourse was characterized by longer chains of student-to-student conversations and more equal student participation. Conversely, when peer leaders used equal amounts of instructional and facilitative discourse, students consistently demonstrated unequal participation and engaged in mostly short chains of interactions. This finding corroborates a number of K-12 studies that have shown that teachers play a pivotal role in both enabling and constraining student discourse (Carlsen, 1993; Crawford, 2005; Hanrahan, 2005; Kelly, Brown, & Crawford, 2000; Klaassen & Lijnse, 1996; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001; van Zee & Minstrell, 1997).

In this chapter, we build on the above findings by presenting detailed analyses of how the conversation unfolds across two extended problem-solving sessions. One of the sessions is led by a peer leader with a largely facilitative style, and the

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other by a peer leader with a roughly balanced use of facilitative and instructive styles. The major research questions we address in this study are: (1) How are students' contributions responsive to those of other students? (2) What types of collaborative discourse practices are used by students working in small groups that lead to building knowledge of chemistry content? (3) What peer leader actions facilitate student collaborative discourse?

The Five Dimensions Characterizing Our Approach

1. Theoretical assumptions. We take a broadly positivist and realist approach: We maintain that individual phenomena, such as conceptual change, and social phenomena, such as conversation, are real and exist in the world, and can be studied objectively. We maintain that learning occurs at both the individual and the social levels of analysis simultaneously; that learning emerges over time; and that an explanation of these emergent processes at either the individual or the group level cannot be complete without a complementary consideration of those processes at the other level (Sawyer, 2005).
2. Purpose of analysis. Our general goal is a practical one: to make PLTL groups more effective at enhancing individual learning outcomes. We seek data that would provide practical advice on how to improve the organization of PLTL groups, how to better design and present problems to be solved collectively, and how best to train peer leaders. Specifically, in this study we hope to accomplish this practical goal by (1) identifying sequences of dialogue among students that indicate engagement with deep concepts, rather than exchange of superficial information, and (2) identifying the contextual factors correlated with these sequences, including group organization, problem design, and peer leader interactional style.
3. Unit of interaction. We follow a fairly conventional conversation-analytic methodology in which the unit of interaction is, at the lowest level of analysis, the adjacency pair, and at a higher level of analysis, an extended sequence of acts that form a coherent episode.
4. Representations. Our representation is the transcript.
5. Manipulations. In our larger study, we manipulated the transcript representation by applying a coding scheme to categorize individual acts. The categories in the coding scheme emerged from a grounded theory approach, and the reliability of the coding scheme was demonstrated by attaining satisfactory intercoder reliability. In the analysis presented here, we do not use this coding scheme; rather, we present a narrative analysis of how knowledge building unfolds differently in the two groups.

Methodology

Both groups were videotaped and transcribed verbatim. The written transcripts were annotated with relevant gestures to include what students were doing when they were not talking. An utterance was defined as a single phrase or sentence spoken by one participant; utterances were delimited by short pauses for breath. A turn was defined as a continuous segment of talk uttered by the same speaker. A single turn could consist of one or more utterances. Each utterance was assigned a code (see Brown et al., 2010). The codes were developed using the constant comparative method of qualitative data analysis (Glaser & Strauss, 1967).

Cohen's Kappa is an inter-rater reliability measure for qualitative studies (Bakeman & Brownlee, 1980; Lunn, 1998). The Cohen's Kappa was 0.91; meeting the criteria for inter-rater reliability (greater than 0.70). All disagreements were resolved through discussions.

Results

In this section, we present turn-by-turn analyses of the conversations that took place in the two different groups as the students solved this problem. These analyses reveal that the first group engages in collaborative discourse exploring the deeper concepts underlying the equations, and that the second group focuses on algebraic manipulation to solve the equations.

When the groups split into two smaller groups to work in parallel on I(*A*) and I(*B*), we moved the microphones to capture the discourse of the smaller groups solving I(*B*). Although both groups took similar amounts of time working on parts I(*B*) and II (916.1 s and 1045.8 s, respectively), the two groups differed dramatically in the ways that they used the time allotted to solve the problem (see Fig. 10.1).

The most dramatic difference is that students in Gillian's group spent more than twice as much time talking as did Matt's students (675 s versus 320.8 s), and Matt's students' spent almost ten times as much time as Gillian's students working

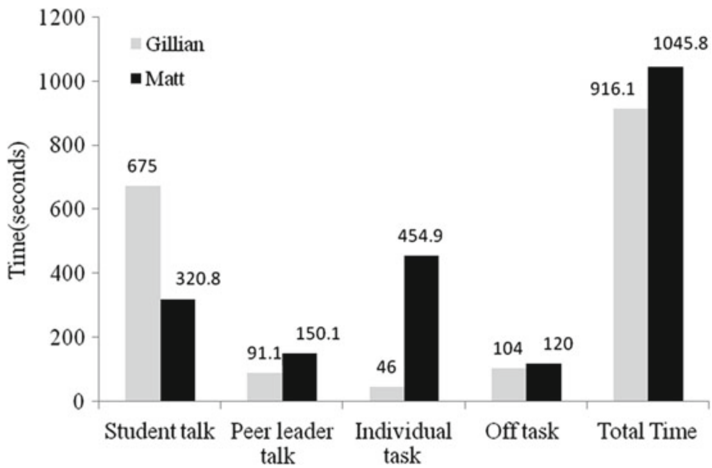

Fig. 10.1 Time of peer leader and student discourse, individual tasks, and off task during Part I(*B*) and II of the de Broglie problem

individually (454.9 s versus 46 s). During their individual task time, Matt's students worked in silence. In contrast, during the 46 s that Gillian's students engaged in individual tasks, they were silent for only 15 of those seconds. Students in both groups spent comparable amounts of time off task (Gillian's students spent 104 s and Matt's students spent 120 s) while their peers spent time writing the group's work on the board. In sum, Matt's students are individually working on the problem and only occasionally interacting with each other; Gillian's students are constantly engaged in conversation.

Extended Analysis of Problem-Solving Discourse

We next explore whether the greater proportion of conversation among Gillian's students might also result in a greater focus on the deeper underlying concepts. Previous research shows that when students engage in learning conversations, they are more likely to address underlying concepts (Hanrahan, 2005; Kelly et al., 2000; van Zee et al., 2001; van Zee & Minstrell, 1997). We also hypothesized that because Matt's students were working predominantly alone, that they might be focused solely on algebraic symbol manipulation (Sfard, 1991) without discussing the underlying concepts associated with the problem.

We begin with an extended analysis of the conversation among Gillian's students, and we find that indeed, their conversations frequently address the underlying concepts. We then turn to an extended analysis of Matt's students; they also solved the problem, but their discourse did not reveal any engagement with the underlying big ideas. Rather, their discourse demonstrated an emphasis on algebraic symbol manipulation. For example, to solve part I(A) or I(B), students can use (9.1) to find the energy of a photon (E_p); (9.2) to find the kinetic energy of the ejected electron (E_k); (9.4) to find to find the velocity of the ejected electron; and (9.3) to solve for the wavelength of the ejected electron, lambda (λ). (The four equations can be found in the dataset description chapter.) In both analyses, we focus on portions of the transcripts that highlight differences in the conversations among students between the two PLTL groups solving the problem.

Gillian's Group: Solving the Problem While Discussing the Underlying Concepts

Gillian's group discusses the equations used to algebraically solve the problem and some of the underlying concepts.[1]

[1] F = Female, M = Male, S = Multiple students in unison, PL = Peer leader.

10 F1: (Time: 32:56.1) So we need the de Broglie wavelength and it's giving us the two wavelengths (referring to the photon) so with the (photon's) wavelength, we can find velocity. And with…

This is correct; the wavelength of the ejected electron is calculated using the de Broglie equation. F1 is correctly noting that the de Broglie equation captures the relationship between wavelength and velocity.

11 F4: And we don't necessarily have to work with the work function right away.
12 F1: Not right away, but we do need it at the end.

Both are correct; the work function is required in the second step of the four steps.

14 F1: Because the important thing is that for the de Broglie wavelength we are finding the wavelength of the electron not of light.
15 F4: Right, exactly. So, first for the electron we use h/mv because we know the mass of…

This is correct; F1 and F4 are demonstrating their agreement with the statement of the problem, and their correct understanding of the de Broglie equation: it captures the relationship between wavelength and velocity for an electron, but not for a photon—that relationship is captured with the light equation. So in lines (14–15), F1 and F4 demonstrate a partial understanding of the big idea that matter has both mass and wave characteristics.

16 F1: We need to find the mass of…
17 F4: No, we know the mass of an electron. It's an electron.
18 F1: Very true, very true.

The mass of an electron is a known number that is readily available in the textbook. In line (16) F1 misspoke, F4 corrects her, and F1 quickly agrees.

19 F4: but we don't know v.

They are on the right track: knowing the velocity of the electron (9.4), the wavelength can then be determined using the de Broglie equation (9.3).

20 F1: With this wavelength (pointing to handout), we would be finding velocity.
21 F2: What did they give us? For the following wavelengths. So, well $\lambda = h/mv$ right?

This is the first time F2 speaks. F2 thinks there is a direct relationship between the wavelengths given and the de Broglie equation (9.3). She seems a bit behind the other two since in line (15) F4 has already mentioned the importance of using the de Broglie equation (9.3) to solve the problem.

22 F4: We can find the energy. I got it.
23 F1: Yes it's telling us to use this, so we can find kinetic energy. (talking over)
24 F4: Of the photon, (pause) right?
25 S: …(inaudible)
26 F1: No, you can find kinetic energy.

This is the correct next step—(9.4) can be used to find the velocity, if the kinetic energy of the electron can be determined—and, the kinetic energy of the electron (E_k) can be determined using (9.2). However, F4's statement in line 24, "of the photon" is incorrect and (9.2) is used to find the kinetic energy of the ejected electron, not the energy of a photon, which is found using (9.1).

27	F4:	Kinetic energy of a photon.
28	F1:	You can use kinetic energy of the work function; $e_k = h\,\nu$ (nu) minus work function. We can find energy of a photon (pointing to board) (talking over, F2: Ohhh, hc/ν, I mean hc/λ) and using energy of the photon we can find the, energy (catches herself using wrong term), the wavelength of light.

In line 28, F1 is trying to work through the algebraic steps necessary to solve the problem. Although finding the energy of a photon is a correct approach (9.1), there are multiple errors in F1's explanation. First, F1 misspeaks; they are finding the kinetic energy of the ejected electron, not "of the work function." Second, F1 suggests that they need to find the wavelength of light; but they were given the wavelength of light in the problem. Hence, F1 appears to be talking backwards through some of the algebraic steps necessary to solve the problem. Finding the energy of the photon (9.3) would be the last step.

At this point, all three students have slightly wrong conceptions of the experiments used to determine that light and matter display both wave and particle characteristics and the relationship between the experiments and equations used to solve the problem (see lines 21, 24, and 28). However, the preceding analysis illustrates that the students are collaboratively working towards a deeper understanding. For example, students asked questions (lines 21 and 24), provided equations (lines 20, 21, and 28), gave explicit instructions for using (9.1–9.4) to solve the problem (line 28), and provided conceptual explanations (line 14). These students engage in collaborative discourse aimed at increasing the collective knowledge of the group.

The students continue to talk about the problem:

36	F4:	(Time: 34:41.0) So first, kinetic energy of a photon we're finding first? What are we finding first?
37	F1:	We need to find first the velocity. Unless you've found it already.
38	F4:	No I haven't found velocity yet.
39	F1:	Ok, so wavelength equals $h/(mv)$, right?
40	F2:	No, wait that's the de Broglie. That's to find the ejected electron. I'm sure, you actually use, I'm sure you probably use the E_k first.
41	F4:	We have to find hc/λ.
42	F4	The energy of a photon equals hc/λ, which we are given. 2.5×10^{-7} m. So that is…

In turn (36), F4 is still using incorrect terminology (i.e., "kinetic energy of a photon we're finding first" when actually they are finding the kinetic energy of the ejected electron). F1 is a bit confused as well; it's true that the velocity of the electron must be found, but it cannot be found until the kinetic energy of the electron is known. Although up until this point F2 has spoken slightly less than F1 and F4, she is correct that the de Broglie equation comes only after E_k is found (line 40).

43	F2:	Ohhh, they gave us the work function because we have to find out if the kinetic energy is greater than zero so that we can say that 1 electron is equal to 1 proton. Do you remember like before?
44	F1:	I know, I remember that.
45	F4:	No it's ejected.
46	F1:	Ohhh, it's ejected.
47	F4:	We do need the work function to find kinetic energy.

F2 is getting close to the conceptual underpinnings: It is true that the work function is a minimum amount of energy that the photon must transfer, "greater than zero." In the latter portion of F2's statement, she misspeaks and says "proton" instead of "photon." F1 also seems to have this conceptual understanding, and says "I know, I remember that." It is unclear whether F4 has a conceptual understanding or whether she has made an assumption that an electron is ejected and the kinetic energy is greater than the work function from the wording of the problem.

At this point, all three students use the light equation to derive the photon's energy from the photon's wavelength (9.1). While students work individually to do calculations, they talk through the steps and values they find from using each equation. F2 does not finish her calculation; F4 and F1 get the same answers, and then use (9.2), the photoelectric effect, to calculate the kinetic energy of the electron. F4 and F1 again get the same answer.

57	F1:	So now using E_k you can find…
58	F4:	E_k = one-half mass times velocity squared.
59	F1:	You can find velocity
60	F4/1:	and then you can find the (point to board) yeah (clapping) (students excited)
61	F4:	Are you with us? (looking at F2)
62	F2:	What, no, not at all.
63	F4:	Ok, we have E_k. We now know E_k (showing F2 work on her paper)
64	F2:	Yes
65	F4:	That equals (1/2) mv^2 and we can find (pointing towards board)(talking over)
66	F2:	This DOES equal velocity. You are awesome. (Laughing)

At line (60), F1 and F4 know they are nearing the solution. While the students work, they talk about the values they get from their calculations. At line (61), F4 realizes that F2 is a bit behind and checks to make sure she understands what they are doing. She does not, so F4 explains that knowing E_k, and using (9.4), the velocity of the electron can be found, and then the de Broglie equation (9.3) can be used to find the wavelength, knowing the velocity. F2, who had earlier emphasized the de Broglie equation (9.3), in line (66) realizes that what is missing from the de Broglie equation is the velocity of the electron. Lines 57–66 illustrate that the students continue to use collaborative discourse aimed at ensuring that all group members understand the problem.

At this point, the students do basic algebra to solve for velocity, using (9.4). F2 is now on board; all three students do the calculations independently and then compare answers to confirm they have the same answer.

The final step is to apply the de Broglie equation (9.3) to find the wavelength, knowing the velocity of the electron:

95	F1&4:	…then λ equals $h/(mv)$, finally.
99	F2:	105th?
100	F4:	Yep.
101	F2:	And then what?
102	F4&F2:	And then λ equals $6.626\times\ldots$

After further calculations, they again confirm that all three have reached the same answer. While students work on their calculations, they check their answers at every step of the process. At this point, the peer leader asks them to write their work on the board, and then asks the second group to write their work. It turned out there was a minor difference in the equations used.

The above analysis shows that students are not applying the equations in a rote manner, but that they are beginning to develop an understanding of the concepts associated with the equations. Students are engaging in collaborative conversations aimed at increasing the collective knowledge of the group.

Matt's Group: Algebraic Symbol Manipulation

In contrast to the group knowledge building observed in Gillian's group, Matt's group focuses on calculations and equations with little discussion of the underlying concepts. The beginning of the students' conversation does not include any reference to, or explanation of, the underlying structure of the problem or the concepts associated with the equations.

5	M	(Time: 11:34.6) Are you doing e photon?
6	F5:	Yeah, and then figure out that (pointing to work) and put it in the work function equation (referring to the photoelectric effect equation).
7	S:	(Time: 11:46–12:05) Individual Task (students are silent)
8	F5:	I got 7.95×10^{-19}.
9	M:	Yep.
10	S:	(Time: 12:07–12:22) Individual Task (students are silent)

During this excerpt, M and F5 engage in superficial talk focusing on the correct calculation. In line 5, M is correct; the energy of a photon is calculated first; however, both students (M and F5) focus on using the equation to calculate the energy of a photon and carry out individual tasks at line (7). F5 (line 8) and M (line 9) demonstrate their agreement about the value for the energy of a photon. M's and F5's discussion consisted of a short-answer question that required recall of equations (see line 6) and non-elaborate answers (see line 8).

After working individually, students briefly exchange information gained from their calculations.

11	F5:	So we know we are going to eject an electron. (Pause)
12	M:	(Nods his head indicating yes)

F5 further demonstrates her understanding of the relationship between the energy of the photon and the work function as she says in line 11, “so we are going to eject an electron”; this relationship is captured with the photoelectric effect (9.2). F5 provides no indication of the meaning of the numbers from which she drew this conclusion.

Students engage in individual work for approximately 25 s, from 12:33 to 12:57. During this individual task work, the students are silent. Then, they discuss the next step in the problem.

17	F4:	Would you use that as the kinetic energy to get (overlapping speech)
18	F4/F5:	*v*?
19	F5:	I think so, don’t you think. (Looking towards male.)
20	M:	I would think so.
21	S	(Time: 13:08–13:16) Individual Task (students are silent)

This is correct; the students are demonstrating their agreement that the next calculation necessary to solve the problem is the kinetic energy equation (9.4). F4 and F5 ask each other algebraic manipulation questions (lines 17 and 18) that do little more than require M to provide non-elaborated feedback (see line 20). Again, the brief conversation leads to students doing calculations individually in silence (see line 21). Students’ discourse focuses on procedural knowledge and using equations to calculate the correct answers and they do not discuss the conceptual reasons for carrying out the mathematics in the problem.

Once the students have finished working individually, they discuss their calculations.

26	F5:	(Time: 14:16.2) Did you get 7.14 × 1,012 for the velocity? (Looking towards F4.)
27	F4:	I got 1.32 × 106. (Pause) Did you square root it? (Looking towards F5.)
28	F5:	Ohhh, good point. (Looking towards F4.)
29	S:	(Time: 14:28.3–15:41) Individual Task (students are silent)
30	F5:	(Time: 15:41.7) did you get 5.51×10^{-10} (referring to the de Broglie wavelength)?
31	M:	No, I think I got the velocity a little different then you did too; so that’s probably the problem.
32	F4:	I got 1.32 × 106.
33	M:	I got 5.44 × 105, so that’s different. (Pause) All right, let’s see. (Male looks over female student’s work) I didn’t get the same kinetic energy.

Although in lines 17–21 the students agree that they need to calculate velocity, they all arrive at different calculations of velocity (see lines 26–33). For example in line 27, F4 had calculated a value of 1.32 × 106 because she used the energy of a photon (9.1) as the kinetic energy (9.4) needed to find velocity; this is incorrect. F5 also calculated an incorrect value for velocity (see line 26) and did not manipulate the equation for kinetic energy (9.4) of an electron correctly to find velocity (line 30) (see also line 38). Meanwhile, M has the correct calculation (line 33). M focuses on the errors F4 and F5 (line 33) made with their calculations. The students do not provide each other with explicit details of their procedures or what confusion formed the basis for the incorrect procedure.

Eventually, F4 notices differences in the equations they used and their calculations.

34	F4:	I didn't subtract the work function.
35	F5:	Weren't suppose to, are we?
36	M:	Well E_k is e-photon minus the work function. (Pause). I thought that kinetic energy was, (Pause) like that. (Pause) (F4 and F5 look towards male.)

F4 and F5 are uncertain if they need to subtract the work function to find kinetic energy (34 and 35). In line 36, M tells F4 and F5 the correct equation, without engaging them in a discussion of the underlying concepts.

The students focus on using the correct equation to solve the problem, instead of working to understand the relationship between the energy of a photon and the work function of a metal.

38	F5:	I thought we only used that (referring to (9.1)) to find out whether or not electrons are actually ejected and once we know that they are, wouldn't they (referring to the ejected electron) have the same energy as the photon? (Looking towards male.)
39	M:	I don't think so. What did you guys use as the …(Talking to other group of students.)
40	F4:	I think you do have to subtract it (referring to Phi).
41	M:	For kinetic energy, did you subtract the work function? (Talking to other group.)
42	F1:	Yes. (F1 is from the other group.)
43	M:	Ok.

In line 38, F5 has an inaccurate understanding and thinks that if the energy of a photon is greater than the work function, then the kinetic energy of the ejected electron is equal to the energy of the photon. Now, she is trying to discuss the concept, but M reverts the group's focus back to the algebraic manipulation and he reconciles the differences in his group members' (F4 and F5) calculations by asking the other small group how they calculated kinetic energy (see lines 39 and 43). Although F4 agrees with M as she says "I think you have to subtract it (referring to the work function)" (see line 40), she does not elaborate, and focuses on the equation rather than the underlying concepts. F4 and F5 do not request a specific explanation; they carry out the setup proposed by M, and verified by F1 from the other group (line 42), to do the algebra necessary to solve the problem.

Now F4 and F5 are on the right track: knowing how to calculate E_k using (9.2).

50	F4:	I got… (Showing her answer to F5.)
51	F5:	Yeah.
52	M:	I multiplied that by 109 in my calculator, so I had 1.34 (referring to de Broglie wavelength). Yes, so that's (referring to de Broglie wavelength) 1.34 nm

After further calculations, all three students in the group (M, F4, and F5) confirm that they have the same answer. For approximately 2 min, F4 writes the problem on the board while students either sit quietly or talk (off task) with the peer leader.

Discussion of Group Contrasts

Gillian's group engaged in extended conversations and exhibited more collective knowledge building. The talk of Gillian's students indicated that they were thinking about the salient features of the problem, and their comments were more often made in coordination with each other, rather than independent of each other (see Gillian, lines10–28; 36–47; 57–66; 95–102). These excerpts show that Gillian's students acknowledged, built upon, and elaborated on each other's ideas when discussing the problem. Extended discourse episodes are associated with the sort of active, participatory activities that learning sciences research shows contributes to deeper conceptual understanding, greater transferability of knowledge, and better retention (Engle & Conant, 2002; Greeno, 2006; Sawyer, 2006; Scardamalia & Bereiter, 2006). Additionally, her students' explanations went beyond algebraic manipulations and began to address the underlying concepts (see Gillian, lines 14; 43; 45–46). A critical component of effective knowledge building is that it supports and facilitates student collaboration as students engage in explaining, clarifying, and debating their ideas (Hiebert et al., 1996; Yackel, Cobb, & Wood, 1991). As a result of their discourse, students collectively improved their ideas through active, intellectual discussions.

Gillian's students used managerial/structure statements and refocusing statements that were directed at collaboration and learning processes. In Gillian's group, students were active participants in making sure everyone understood the process necessary to solve the problem, and all students made intellectual contributions (see Gillian, lines 61–65).

Gillian's group displays the sort of group knowledge building discourse that is currently advocated by the science education research community. Their collaborative problem-solving conversations provided support for, and challenged, individuals' thinking. Over time, the students' ideas became more coherent and elaborated. Two discursive moves made by the students—elaborating on each other's ideas, and self-monitoring the group's understanding of the content—enabled knowledge-building discourse. In these ways, Gillian's students engaged in what (Lave & Wenger, 1991) called a "community of practice," where the goal was to support both the growth of individual cognitive advancement and the collective knowledge of the group. Many education researchers have stressed that once a collaborative group culture has emerged, it can motivate and engage students in knowledge building and in constructing understandings that support integration and application of the content (Blumenfeld, Kempler, & Krajcik, 2006; Engle & Conant, 2002; Greeno, 2006; Sawyer, 2006; Scardamalia & Bereiter, 2006).

Matt's students exhibited shorter discourse episodes, frequently engaged in individual tasks, and mostly provided each other with algebraic manipulations that did not deal with the underlying concepts. Our analyses show that the questions asked by Matt's students were often task-oriented and used to coordinate the group's interactions (see Matt, lines 5–10; 17–21; 26–33; 34–35; 38–43) in preparation for individual tasks (see Matt, lines 7; 10; 21; 29). The lack of explicit focus on the important features of the problem and underlying concepts led students to a false sense of competence. During one episode, although all three students discussed and agreed upon the equations to use, they all arrived at different calculations. Our analysis revealed that the students had, in fact, not all used the same equation (see Matt lines: 26–33). Webb (1995) suggests that asking closed questions and providing non-elaborated help involves less cognitive restructuring or clarifying on the part of help-givers and does not enable help-receivers to correct their misconceptions or lack of understanding.

Not only did Matt's students focus on getting the correct answer, but the participatory structure was unequal. Students in Matt's group held different positions according to their perceived competence. For example, the male consistently initiated ideas and validated his peers' conceptions (see Matt, lines 5–9; 11–12; 17–20; 26–33; 34–36; 38–43; 50–52). It appears from the transcripts that students in Matt's group adopted an unequal participatory structure where the male in the group was viewed as an authority.

In summary, Matt's group was ineffective at promoting group knowledge-building discourse; students focused instead on individually attempting to understand the content. Neither the students nor the peer leader encouraged in-depth conversations of the underlying concepts associated with the problem. The excerpts demonstrate that students in Matt's group showed little evidence of building upon, debating, and elaborating upon each other's ideas.

Conclusion

There is a great deal of research evidence that students who participate in PLTL acquire higher levels of chemistry understanding than students who learn individually and alone. However, no studies have looked inside the "black box" of the PLTL session to examine exactly how peer discourse contributes to chemistry understanding. This study has shown that not all peer group experiences are equally effective at promoting student knowledge building. First, we investigated how students' contributions were responsive to those from other students. We found that in Gillian's group, students engaged in intellectual conversations where they asked each other questions, provided procedural and conceptual explanations, and checked each other's understanding of the problem. Even while Gillian's students worked on individual tasks, they constantly talked about their calculations with each other. In contrast, the discourse of Matt's students rarely included any reference to, or explanation of, the equations or underlying concepts. The conversations in Matt's group were mostly superficial; students provided each other with equations and non-elaborated explanations. In Matt's group students' discourse focused on the algebraic steps necessary to solve the problem.

We found that Gillian's students frequently elaborated on each other's ideas and self-monitored the groups' understanding of the problem in part I(*B*). Even though at times Gillian's students had slightly incorrect conceptions, as a result of their discussions they collectively developed a better understanding of the problem.

Conversely, in Matt's group, there was little evidence that the group jointly developed a more in-depth understanding of the content from their discourse; rather, their conversations focused on rote application of formulas and calculating a "correct" solution.

Implications for Practice and Research

Examining student discourse also has implications for the redesign of PLTL problems. Although the problem was basically a closed question, with a single correct answer, we expected a different type of peer leader and student discourse than we observed. First, we thought that students would discuss the underlying concepts associated with the problem based on their experiences in lecture and recitation sessions. Second, when the students failed to engage in conceptual discussions on their own, we thought that the peer leader would challenge students to verbally explore the concepts involved with the problem. Based on the current study, we plan to redesign many of our PLTL problems. We recommend that chemistry instructors design PLTL problems to begin with guiding questions that allow for students to discuss key concepts and experiments in addition to equations and variables. The purposes of these guiding questions are to unveil students' prior knowledge and review the phenomena discussed in lectures, recitations, and other problems. Once students have identified the important ideas associated with the phenomena, the problem set should provide students with the opportunity to apply equations and concepts to other contexts. Altering existing problem sets to provide explicit questions that have students discuss phenomena before problem solving may engage students in higher-order thinking and alter students' interactions with each other and the peer leader. Redesigning the problem sets could provide an even more active environment for students to engage in science discourse and further improve students' conceptual understanding of the problems they solve in PLTL. Hence, future research is needed that investigates whether revising PLTL problems in this way does in fact foster the type of conversations that lead to deep conceptual understanding. Restructuring the problems could favorably affect student's chemistry understanding, critical thinking, and knowledge building from collaborative discourse.

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