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The Influence of Group Dynamics on Collaborative Scientific Argumentation

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Research has addressed what instructional conditions may inhibit or promote scientific argumentation. Little research, however, has paid attention to interpersonal factors that influence collaborative argumentation. The present study examines the ways interpersonal factors affected group dynamics, which influence the features of collaborative argumentation among three groups of students of different ability as they collaborated to explain a complex scientific question. We transcribed and coded videotapes of three groups of 7th grade students while they performed an online science investigation and explanation. Methods included contextual analysis, discourse mapping, and qualitative case comparison. The results suggested that the clear goal of task completion allowed a single member to dominate group discussions, which prevented substantive argumentation. Students were mainly concerned about task identification and talked less about the meaning of their data. Our analyses suggest that social conflict may promote more substantive argumentation. We discuss ways to support more sustained argumentation during collaboration.

Keywords: Argumentation, collaboration, interpersonal factors.

INTRODUCTION

Recently, the focus of science education has significantly shifted from content acquiring to engagement in science practices. Among these practices, argumentation is now recognized as a central practice of science and thus a crucial aspect of instruction that aims to help students develop a robust understanding of science (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Kuhn, 1993; Sandoval & Millwood, 2005). This emphasis stems from recently articulated views of science that emphasize the deeply social aspects of knowledge construction in science (Duschl, 2008b; NRC, 2007; Ryu & Sandoval, 2012). There is a burgeoning research base on the ways that students argue in science classrooms across a range of science activities. Naturally, since argumentation generally occurs between people, much of this research has occurred in collaborative contexts. To date, despite growing recognition, research on scientific argumentation has focused on the structural patterns that arguments take, with the primary goals of comparing those patterns to ideal forms of argument and exploring was to improve them (for review, Jimenez-Aleixandre & Erduran, 2007).

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One element missing from studies on collaborative argumentation is the influence of social factors in group dynamics affecting productive collaboration on the arguments students make. This is an important element to understand, since the literature on collaboration shows that navigating social relations is a major part of collaboration. Consequently, the present study attempts to relate structural features of student arguments to interpersonal aspects of group dynamics on their collaboration. We examine in detail the collaborative work of three groups of students with different levels performance in science as they explore a large data set to explain a complex question of photosynthesis and plant ecology. Our analyses focused on the decisions that each group made during their investigations: about

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State of the literature

- Science education generally shifts its emphasis from acquiring content knowledge to engaging in science practices.
- Research on scientific argumentation has focused on the structural patterns that arguments take, with the primary goals of comparing those patterns to ideal forms of argument and exploring was to improve them.
- Research on the influence of social and interpersonal factors on collaborative argumentation is needed.

Contribution of this paper to the literature

- This paper contributes to the literature about student collaborative scientific argumentation.
- This paper contributes to the literature regarding how social, interpersonal dynamics affect productive collaborative argumentation.
- This paper contributes to the literature about designing learning environment to foster scientific argumentation.

what to do, what data to get, what data meant, what claims to make, and how to justify those claims. Such decisions, at least potentially, require students to resolve disagreements.

BACKGROUND

Research on collaborative argumentation in science is relatively recent, while research on collaborative learning has a somewhat longer history. Argumentation research has uncovered some consistent patterns in students' arguments. Collaboration research has focused on what makes collaboration productive, including group membership and forms of participation. Our approach in the current study is to apply a lens on interpersonal interaction borrowed from collaboration research to student argumentation.

Patterns of Argumentation during Collaboration

As argumentation has become recognized as a crucial form of scientific practice there have been a burgeoning number of studies of collaborative argument in science classrooms. These studies have examined a range of tasks and topics, with a set of fairly stable findings about the patterns of student arguments emerging from these works (for review, Sampson & Clark, 2009). One finding from this area of research is that students commonly advance claims without providing explicit justification (Duschl, 2008a; Erduran, Simon, & Osborne, 2004; Jiménez-Aleixandre, 2008; Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Kelly, Druker, & Chen, 1998). Students appear to justify claims only when challenged, and even then not always. Another finding that emerges from these studies is that students appeal to an array of warrants to justify their claims, including empirical evidence, theoretical ideas, or personal experience (Bell & Linn, 2000; Kelly et al., 1998).

One of the criteria of good arguments, then, has been the presence of various responses to alleged claims, including challenges for justification, counter-arguments and rebuttals, and other epistemic operations (Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Kuhn, 2005). Consequently, a primary aim of research on collaborative argumentation has been to map out the sequence of moves that interlocutors make during an argument and to examine the resulting argument structure in terms of its fit with models of appropriate argument. The most commonly used model in science education has been Toulmin's (1958) argument pattern. Researchers have used this scheme to document the claims, warrants, backings, qualifiers, and rebuttals that students make during arguments. In practice, a strict application of Toulmin's argument pattern is difficult (Erduran, 2008; Erduran et al., 2004), but it remains a popular approach to characterizing argument structure. Some have argued (Duschl, 2008a) that the application of Toulmin's pattern in science education has ignored Toulmin's own point that the quality of particular arguments is what he called "field-dependent." That is, the structure of an argument alone does not capture the extent to which warrants are appropriate justifications or proper rebuttals that make sense. Such judgments can only be made within fields (or disciplines) and rest of analyses of the substantive content of arguments.

Analyses of the substance of student argument in science classrooms, conversely, have generally not included structural analysis. These content-based analyses of collaborative problem-solving contexts suggest that students can fail to argue, or short-circuit argument, when such arguments are warranted by, for example, incorrect or incomplete claims (Coleman, 1998; Hogan, Nastasi, & Pressley, 1999). On the other hand, extended opportunities for argumentation, especially when scaffolded in terms of the purpose and criteria for arguing, seem to help students learn science and to produce somewhat better arguments (Jiménez-Aleixandre, 2008, reviews a number of these studies). Arguments appear to promote conceptual change in participants, at least sometimes (Bloom, 2001; Roschelle, 1992).

Throughout this work, however, little attention has been paid to how interpersonal relations between collaborators affect how they argue. Findings from research on collaboration suggests that such relations should be expected to have a strong effect on students' arguments. In particular, the apparent failure of students to argue when it seems it would be productive to do so may arise from interpersonal influences.

Interpersonal Influences on Group Dynamics and Collaboration

Research on group learning emerged in the 1970s, with a major focus of early research being the relative benefits of competition and cooperation, and of group performance compared to individuals. This was followed by studies examining factors that influence group performance, especially those related to group composition. This research has been summarized in two major reviews by Webb (Webb, 1982; Webb & Palincsar, 1996). The primary benefits of group work appear to stem from giving and receiving help. Not surprisingly, these benefits accrue when trying to solve problems that are hard for individuals to solve on their own. Group composition appears to matter, but results are somewhat mixed on this point. Some of the studies reviewed by Webb and Palincsar suggest that groups comprised of members with similar ability perform better than mixed-ability groups, whereas others suggest that mixed-ability groups outperform same-ability groups. The benefits of mixed-ability grouping seem to go mostly to students of lower ability, who tend to learn more through interactions with more capable students than when working with others at their own ability level (Webb, Nemer, Chizhik, & Sugrue, 1998). A recurring finding in more recent research is that groups with the same or similar ability groupings often vary greatly in their performance on identical problems (Barron, 2000; Hogan et al., 1999)

The variability in group performance seen in early research on collaboration led researchers to look more closely at how students interact while they work together. These more recent studies suggest the strong impact of social an interpersonal relationships on group performance. Much of this research suggests the challenges that students face in coordinating differences in experience, values, and goals during collaboration (Barron, 2000; Forman & Larreamendy-Joerns, 1995; Hogan et al., 1999). These obstacles are in many ways cognitive, as students have to think about what they think, think about what their collaborators think, evaluate these multiple ideas, and so forth. Yet, the obstacles are also social as power dynamics within groups greatly affect who participates during collaboration and how (Barron, 2003; Hogan, 2002; Lomangino, Nicholson, & Sulzby, 1999).

One framework for characterizing the joint cognitive and social demands of collaboration is Barron's (2003) dual space model. Barron proposes that individual students must navigate collaboration in two spaces, the *content* space of the particular problem that students are trying to solve, and the *relational* space defined by members' interpersonal interactions. In her study, Barron found that less successful groups were less responsive to each other, either ignoring group members' contributions or rejecting them without discussion. More successful groups are more responsive, and their interactions are marked by high rates of acceptance and agreement of each others' contributions (Barron, 2003; Hogan et al., 1999). Besides these characteristics of interaction, Barron (2003) cites research suggesting how power dynamics affect interaction. Specifically, group members with low social status are often ignored and friends, perhaps not surprisingly, tend to engage more productively with each other.

Our goal in this study is to combine an analysis of group argumentation with an analysis of the interpersonal dynamics within groups. Collaboration research shows clearly that interactional differences lead to performance differences. With respect to argumentation, we could assume that claims put forth by low status group members are likely to be ignored, thus short-circuiting argument. Further, if groups fail to maintain joint attention it seems unlikely that they can sustain complex arguments. Ultimately, then, we could also assume that the success particular groups have at collaborative argumentation may rely more on how students get along rather than on what they know.

Table 1. Profile of Students in This Study, According to Group Membership

Student	Gender	Pre-test score (%)
Low Group		
Jack	Male	60
Dan	Male	60
Karen	Female	66
Middle Group		
Beth	Female	74
Ruby	Female	74
Bonnie	Female	77
High Group		
Andrew	Male	91
Bryan	Male	94

METHODS

The purpose of this study is to relate patterns of social interaction within groups to the arguments those groups constructed during a collaborative investigation of a complex data set to explain plant variation between micro-climates in a southern Californian coastal mountain range. We examine three groups of varying ability levels with a particular focus on the arguments these groups had as they attempted to make collective decisions to mange their investigations. Our general approach was to characterize the structure of group arguments and relate to characteristics of groups' social interactions.

Setting and Participants

This study focuses on three groups of students in one seventh-grade science class with 33 students (20 boys and 13 girls). The class was in a public, urban middle school located in a middle-income neighborhood in metropolitan Los Angeles. The ethnic composition of the school at the time of the study was 75% Caucasian, 14% Latino, 10% Asian American, and 1% African American. Twelve percent of the students at this school received free or reduced lunches. The class was participating in a pilot test of a guided inquiry curriculum on plant adaptation, to be described below. The three groups studied here were nominated by their teacher as representing low, middle, and high achieving students. For this collaboration, the teacher composed all of the groups in the class. Performance characteristics of each of the students in this analysis are given in **Table 1**. Notice that the students' performance on the pre-test of this unit supported their teacher's nomination of their ability level. Note also that given what is known about collaboration, the low ability group could be expected to struggle during their investigation.

Instructional Context

The collaboration we analyze here occurred during students' participation in a three week guided inquiry unit on plant adaptation called *Sensing the Environment* (Griffis & Wise, 2005). This unit began with the entire class looking at a photograph of a section of the Santa Monica mountains in southern California. The class observed a number of visual differences in the kinds of plants that populated different parts of this picture, which included a sunny west-facing hillside, a shaded creek valley, and an east-facing hillside that received less sun than its counterpart across the creek. The teacher used students' observations to frame the question, "why do plants look different?" This question drove the unit's activities, including labs and other activities to explore the processes of photosynthesis and transpiration and to encounter an idea that ecologists call the photosynthesis/transpiration compromise. This compromise refers to the way that the regulation of transpiration, the evaporation of water from leaves that pulls water from the roots throughout the plant, constrains the rate at which plants can photosynthesize. If plants transpire too quickly they can dry out and die, but if they do not transpire they cannot photosynthesize, both because water needed for photosynthesis cannot move to the leaves and because the cells that open to allow water out also allow carbon dioxide, another ingredient of photosynthesis, in. From these labs, students worked together in groups of two or three over the course of three days to examine data collected by remote sensors deployed in the areas they observed in the photograph from the first day. These sensors collected temperature, humidity, and light intensity (measures as the amount of photosynthetically active radiation, or PAR) at each of 3 locations: the two hillsides and the valley mentioned above.

These sensor data were online and groups explored variable relationships through a query interface that allowed them to compare single variables across sites (e.g., temperature at site 1 and site 2) or two variables at a single site (e.g., temperature and humidity at site 3). Students could specify a time range over which to view these comparisons and the kind of aggregation they wanted to see (e.g., average weekly temperature). Students could also examine a gallery of photos of leaves taken from plants that lived close to each sensor site. Students were asked to use the data they generated to propose an explanation to the answer of why plants looked different. Based upon their activities to this point, they were expected to explain leaf size variations in relation to variations in the three environmental variables they could observe. To help them produce these explanations, students were provided with a set of guiding questions to try to answer, reflecting a decomposition of the explanatory problem. Groups collaborated to examine data and to answer the guiding questions, although students individually wrote their own explanations to the driving question immediately following their collaborative work. The online investigation interface is shown in **Hata! Başvuru kaynağı bulunamadı.**.

Data Sources and Analytic Methods

Each of the three groups was videotaped during each of the three days of collaboration, yielding approximately three hours of video for each group. Groups were videotaped from behind as they worked around a single computer in an effort to capture student interaction and the computer screen. Yet, it was sometimes difficult to observe students' facial expressions or gestures because of this setup. Still, it was

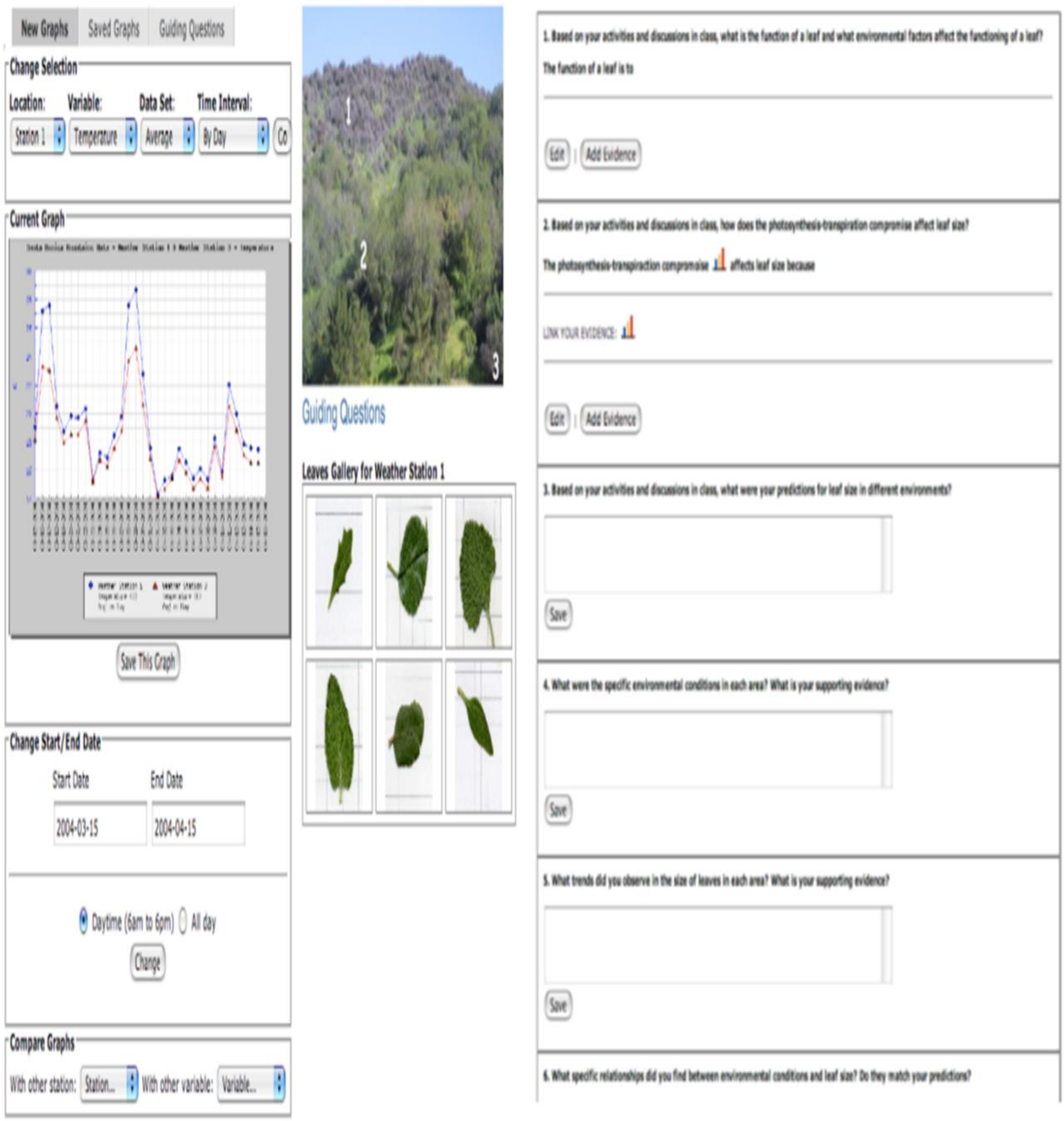

Figure 1. Online investigation interface. The left side shows the data query and graphing interface. The right side shows the guiding questions and space for groups to record their answers

always possible to identify which group member was talking at a given time, and the setup used generally enabled to see how students interacted over what was on their computer screen. The video was analyzed using methods of interaction analysis to identify events of interest. These events were then transcribed and analyzed.

We developed codes both deductively and inductively and merged them into one final set through an iterative process. To prepare predefined codes in the framework of a given theory, we used previously developed models of arguments (von Emeren,1996; Duschl,2007; Osborne et al. 2004) and collaboration framework (Barron, 2003). Besides deductive codes, we also utilized bottom-up coding (inductive approach) that allowed input of new emerging concepts form the data. In order to merge the data, we coded randomly selected 20-minute transcripts from each group with deductive and inductive code sets separately, and compared and merged them. The merged code was then applied to another 20 minutes transcript to confirm codes. A text management program, ATLASti, was used to facilitate the iterative process of refining codes. All statements and non-verbal behaviors on the transcripts were coded.

Table 2. Types of Group Decisions Observed in This Study

Decision types	Description
Task identification	A group agrees to what they need to do next, why they need to do something
Turn taking	A group agrees to turn around, you do it
Data interpretation	A group agrees with an idea about data, identifies relations between variables
Data description	A group agrees a description of what data look like
Data report	A group agrees to report, record data, create graphs
Asking question	A group member asks contents-related question and get answers as a decision making point
Technical issue figuring	A group figures out how to operate functions of the web site such as saving graphs, editing evidence, and viewing the leaf gallery
Confusion	A group agrees that they don't know what to do

In order to find emerging patterns, we constructed discourse maps (Hogan et al, 1999; Frederiksen, Roy & Chan, 1996), arguments sequence maps, and qualitative case comparison. Discourse maps showed the sequence of conversational turns and contents of the conversations in order to see who said what under certain circumstance, which was useful to identify relative power status. An arguments sequence map described the sequences of argumentative operation for each and across decisions, which showed the argumentation pattern for each group. Drawing on grounded approach, we used the constant comparative method (Glaser & Strauss, 2009) to identify interrelated aspects between arguments patterns and interpersonal dynamics patterns. We first selected a few episodes of interests, compared them to other episodes to decide similarity and difference, and then captured the representative characteristics of episodes to develop codes iteratively.

Identifying Decision-Making Events

A decision making event was determined as a unit of analysis for two reasons. First, not only students' individually different goals, perspectives and personalities can be reflected, but also their social goals and relations are reflected when they need to make decisions together. Second, arguments can be prompted while they make decisions.

We took the view that decisions needed to be continually made across the collaboration because members of a group cannot make progress without making an implicit or explicit decision. A decision is identified from the moment that one proposes an opinion or question and finishes the moment that group members make explicit agreements or take action.

We then identified in what contexts the groups made decisions. We categorized decisions into types according to the function they served for the groups, as described in **Hata! Başvuru kaynağı bulunamadı.**.

Identifying Argument Structures

In order to investigate how the groups of students argued in their decision making processes, argumentative operations were examined and then the chronological sequences of the operations were constructed. Because the investigation aimed to examine to what extent, and how interactively students engaged in argumentations rather than judging the structural or conceptual quality of arguments, the argumentative operations codes characterized dialectical moves of arguments (Table 3). In addition, justification partly adopted Duschl's (2008) coding scheme because the scheme reflected frequently used justification methods at the middle school level.

After the argumentative operations were identified for each statement, a sequence map that depicted both dialectical moves of argumentation for each decision and chronological orders of arguments across decisions was constructed for each group. The sequence map facilitated researchers to see emerging patterns of each group's argumentation.

Characterizing Interpersonal Dynamics

Interpersonal dynamics, particularly students' power conflicts, were identified in order to address how their efforts to protect/challenge power status influenced student arguments (Table 4). Power relations among group members can be characterized in three categories: indication of equal status, relative status (e.g. presence of dominance), and power struggle to protect/challenge power. While prior research viewed students' status as a static characteristic determined by socioeconomic, or cognitive factors (Lomangino et al, 1999), recent research has shown that status is negotiable and can change depending on the situation. Thus, this study focused on this negotiable power status because we expected that students could use their arguments to protect/challenge power status.

We present our findings in two parts. First, we examine the decision-making events in all three groups

Table 3. Argumentative Operations Coded in These Analyses

	Argumentative operation (Code)	Description
Claims	Claim(C)	Student makes a claim that states a position without supporting it
	Reasserting claim(RC)	When there is a disagreement, student articulates claim again but without supporting it with evidence
Oppositions	Disagreement(D)	Student uses explicit verbal expression or action stating they cannot do what is proposed
	Rebuttal(RB)	Student restricts the opponent's argument. Revealing the unknown weaknesses of the argument
	Accepting rebuttal (AR)	Student accepts their weaknesses or wrong points after those points were revealed or pointed out by others
	Counter argument(CA)	Student challenges provided opinions by making alternative claim
Justifications	Asking warrants(AW)	Student requests explanation connecting claim and evidence
	Cause and effect(CE)	Student refers to premises that are casually linked to a non controversial effect
	Using analogy(UA)	Student uses a similar case to support a claim
Agreements	Confirmation(CF)	Student repeats answer to confirm and check out it again when there is a provided answer or opinion e.g. “Amounts of water” “Amount of water, right?”
	Explicit agreement(EA)	Student makes a verbally explicit agreement. e.g.) I agree with you. OK, all right. Let’s do that, great idea. Good.

Table 4. Analytic Codes Related to Power Struggle within Groups

Codes	Description
Complain	Student indicates dissatisfaction with a certain action taken
Criticize	Student judges an action unfavorably or harshly
Disengage	Student does not participate in an activity currently going on
Distracted	Student is involved in something that is not part of the group’s suggested approach
Ignore	Student does not respond to others when expected to or does not listen to others’ opinions
Control	Student comments on the screening, monitoring and organization of roles for their task
Evaluate	Student judges or determines significance, worth or quality of what other members did
Take controlling of computer	Student moves laptop computer in front of his/her seat and types something

Reliability

All of the codes presented here were developed, refined, and applied by the first author. To establish reliability, a second coder unfamiliar with the project was trained in the coding procedure. After training, the second coder independently coded a random selection of 20% of the transcripts. Reliability was calculated with Cohen’s Kappa. Kappa was .70, which is acceptable.

FINDINGS

and the patterns of argumentation around those decisions. This provides an overview of the amount of argumentation in each group and what each group argued about. Following this we describe the interactional patterns observed in each group, as they differed substantially from each other. In these case narratives we characterize how the interpersonal dynamics between group members affected their decision-making and argumentation.

Overall Decision-Making and Argument Patterns

The frequency of decision types with and without arguments is presented (**Table 5**). The Middle-achieving group made many more decisions (41) than the other two groups (Low 23, High 21), and they also argued about these decisions much more than the other two groups. The Middle group argued over 97% of their decisions, compared to 65% by the Low group and 76% by the High group.

Table 5. Summary of Decision Making events and Arguments across Groups

Decision types/ group	Low		Middle		High	
	Arguments (N/%)	No arguments (N/%)	Arguments (N/%)	No arguments (N/%)	Arguments (N/%)	No arguments (N/%)
Task identification	7(30.4)	1(4.3)	13(32.5)	2(5.0)	5 (23.8)	1 (4.8)
Turn taking	1(4.3)	.	1 (2.5)	.		.
Data interpretation	2(8.6)	.	9 (22.5)	.	5 (23.8)	.
Data description	.	.	2 (5.0)		1(4.8)	1(4.8)
Data report		3(12.9)	2 (5.0)	.	3(14.3)	.
Asking and answering questions	2(8.6)	.	5(12.5)	1(2.5)		2(9.6)
Technical issue figuring	3(12.9)	1(4.3)	4(10.0)	.	2 (9.5)	1(4.8)
Confusion	.	4(17.4)	1(2.5)	.		
Total	15(65.2)	8(34.8)	37(92.5)	3(7.5)	16(76.2)	5 (23.8)

Table 6. Low Group's Sequence of Decisions and Arguments

	No	Decision Types	Arguments Sequences		No	Desicion Types	Arguments Sequences
Day1	1	TI	C(K)D(J)		12	FT	.
	2	FT	C(J)CF(K)		13	CON	.
	3	TI	C(K)D(J)		14	TI	C(J)
	4	CON	.		15	ACR	C(J)
	5	TI	C(J)	Day3	16	ACR	C(J)EA(D)
	6	TI	C(J)		17	FT	C(D)RU(J)CE(D)CA(J)
	7	DD	C(J)		18	CON	.
	8	DR	.		19	TI	.
Day2	9	CON	.		20	DI	C(J)CA(D)RC(J)AW(D)CF(D)
	10	FT	C(K)D(J)		21	DR	.
	11	TT	C(J)		22	TI	C(D)CA(J)RC(D)AW(J)CF(J)
					23	DR	.

In all three groups, task identification was the decision most often argued about, although the High achieving group argued about this less frequently than the other two. The Middle and High groups also argued often about how to interpret specific data, whereas the Low group rarely argued about this. An interesting trend in these patterns is that arguments about data (its description, interpretation, or reporting) increased as group ability increased. Only 2 (8.6%) of the Low group's 15 arguments were about how to interpret data, and none concerned data description or reporting. About one third (32.5%) of the Middle group's arguments concerned data, while 43% of the High group's arguments were about data. Two other trends stand out in **Table 5**. First, both the Low and Middle groups grappled with a relatively high incidence of trouble figuring out how to work the software (Technical issues). Second, the Low group had several decision-making attempts end merely in assertions of confusion about what they were supposed to do. Neither of the other two groups faced that obstacle.

As might be expected, then, the patterns here suggest that the Low ability group struggled to identify and agree on what their tasks should be, while arguing very little about how to make sense of the data they were looking at. In contrast, the High ability group spent much of their time productively arguing about their data. The Middle group looked more like the High group overall.

Interpersonal Dynamics of Arguments

In this section, we explore the differences in decision-making and argument between these three groups through a presentation of the sequence of decisions and arguments made by each group. These sequences show how the group's argumentation evolved over the course of their three day collaboration. We present examples of some of the arguments that appeared to be key to each group's collaboration to show how interpersonal dynamics manifested themselves within these arguments. Each argument a group had is presented as a sequence of argument moves. These moves are abbreviated using the codes described above in **Table 3**. Each coded argument move is followed by a letter in parentheses, representing the first initial of the person making that statement.

Low Achieving Group

Table 6 shows chronologically arranged argument sequences and decision types for the low achieving group. This group's arguments mainly dealt with identifying their tasks or figuring out technical functions. The low achieving group made a relatively smaller number of arguments (14 out of 23 decisions), and only a few rebuttals, counter arguments, and justifications were observed (1 rebuttal, 2 counter arguments, 3 justifications).

However, most of the arguments from the group finished with Jack (J)'s sole claim, and the other members, Karen (K) and Don (D), did not make further moves after Jack's claim. Although Karen occasionally made claims on the first and second day, her claims were blocked by Jack's disagreements, and there was no further response after Jack's disagreements. Unlike the first two days, more interactive arguments between Jack and Don were observed on the third day. Don's engagement on arguments seemed to have increased, while his participation had been very limited on first two days.

In order to answer why Karen's claims were blocked by Jack, and what made Don argue more actively on the third day, but not on the two other days, the students' interpersonal and interactional dynamics were examined. Jack and Karen seemed to have different goals: while Karen seemed to want to quickly finish the tasks, regardless of quality, and engaged in various digressions with other group members, Jack clearly seemed to concentrate more on their online investigation and thereby provided answers. Their different goals gave rise to conflicts, particularly when the group was confused about answering a questions or figuring out what was going on. Jack concentrated on the task and tried to consider solutions, but Karen seemed to see the group's momentary stoppage (caused by confusion) as an opportunity to start a digression.

Jack: One thirty one divided, ugly there is no divide
Jack: Do you know how to use calculator? (Jack asked this to another group and no one responded)
Karen: Just do whatever, try that one
Jack: There is too many of these
Jack: Pen please
Karen: My cousin XXX, she was very sick and she suffered a lot cause, her fever, and she suffered a lot
Jack: Six point two, ah
Karen: She so cute, do you have a cousin?
Jack: [Jack doesn't respond]
Karen: Hey, you don't say thank you
Karen: I just wonder how guys react when saying that, that's not very nice
Jack: O.K. thank you
Karen: Is that a good thank you? Or bad thank you that makes me shut up
Jack: Fine

In the example above, when the group did not figure out how to divide when using a computer calculator to average surface areas, Karen said, "Just do whatever" and started talking about her family and her cousin's family. Jack did not respond to Karen's digression, and asked for help from other groups to let him know how to divide on the computer. After a while, when Jack realized that he made a mistake trying to divide a number by zero, he criticized Karen because she was not at her seat while he was trying to calculate average surface area, and pointed out that she stayed too long at the lady's bathroom. Karen answered that she was not at a bathroom, and said "I'm so disappointed that you thought that I was in a bathroom." Jack neither apologized nor made any soothing comments toward Karen, who started talking to Don and asked where his family originally came from. Don simply answered with his family origin, and began to watch the computer screen. Then, Jack said "She wants to buy you the soda from XXX," and Karen became quiet. Karen's demonstrably lower dedication to their task, and her making digressions, seemed to lead Jack not only to criticize and complain about her, but also to ignore her claims. Being ignored and criticized by Jack, Karen became disengaged and distracted, and did not participate in arguments at all on third day, although she continued her attempts to start digressions. She left her seat more often, and for longer periods, than on the previous two days.

Don, who initially stayed quiet and just looked at how Jack provided answers for the first two days, learned from Jack on the beginning of third day how to generate graphs and add evidence:

Jack: Click here, and (select) two (Jack pointed out the screen and asked Don to select site 2)
Don: Oh, oh yeah. I just clicked
Jack: You took the two, and go, go to the temperature, ok temperature
Don: All right (He followed Jack's instruction and found temperature from the pull down menu)
Jack: All right, then go to "by day" (Jack asked Don to select by daytime scale variable)
Jack: And, now click graph and save
Jack: And then, type for the graph
Don: What?
Jack: Graph's name, section 2, humidity and temperature (Jack informed Don that Don needed to type a title of graph and brief description for it)
Don: Ok, very nice

After that, not only his technical competence increased, but also his participation in arguments; Don started to voice his opinion about their tasks. For example, Don provided a claim that it was necessary to make a comparison graph between light intensity and humidity. Although Jack provided a rebuttal that they could not make such a graph (Jack pointed out that the graph function did not allow making a graph showing two variables at the same time for the same site), Don reasserted his claim, stating that light intensity and humidity are "related to amounts" contributing to the different look of leaves. While Don's justification was unclear and he did not fully figure out graphical functions, it is worth noting that he seemed to be trying to make sense of the meaning of observed data (light intensity and humidity) to provide an explanation (why leaves look different).

In summary, the student in this group who mainly managed the tasks and provided answers and guiding questions was Jack. He had a clear goal of concentrating on their tasks. He also encouraged Don to contribute better to their activity. However, it is questionable why Jack did not teach Don earlier than the last day, although he continually requested more contribution from other members across their online investigation. Karen, who wanted to hang around with group members and made lots of digressions, was criticized by other members, and her contribution to the group's argument was very limited. Don, who had limited computer skills and was relatively quiet, increased his participation after he learned how to create graphs and add evidence and more actively participated in arguments.

Middle Achieving Group

Table 7 shows chronologically arranged argument sequences and decision types for the middle achieving group. Most of this group's arguments were about task identification and data interpretation. The group made the largest number of arguments (37 arguments out of 40 decisions), and also engaged in a numbers of interactive arguments, most of them on the second day.

On the first day and the first part of the second day, the middle achieving group's arguments centered around Beth (B)'s claims. Ruby (R)'s contribution was limited during these two days, after the following discussion when she asked about the relationship between temperature and height:

Ruby: what would be hotter at the top of the mountain or at the bottom?
Beth: bottom because the top is more closer to sky, it is more closer
Ruby: are you sure? Heat rises
Bonnie: yeah heat rises in like a room but
Beth: in the top of a mountain it is as you are like really high up in the air
Bonnie: Because you know at like Big Bear, it is like cold and you are like 3000 feet up in the air
Ruby: yeah
Beth: and like on Mount Everest it is like super cold on the very top but it is not very cold well it pretty cold on the bottom but it is not as cold as on the top why are we even talking about that
Bonnie: because I am just at the top
Ruby: [she shakes her head and slightly raised her right hand]
Beth: O.K. We are explaining, so you need to listen

In the example above, when Ruby asked why the top of mountain is colder than the bottom even though warm air goes up, Beth and Bonnie did not provide explanations although they used a couple of examples. Beth also made comments such as, "Are we even talking about that?" or "We are explaining so you need to listen," which might have made Ruby feel a little bit uncomfortable.

In addition, although Bonnie (N) occasionally made claims on the first and second day, her claims were blocked by Beth's disagreements, and there was no further response. The interactional dynamic between Bonnie and Beth was similar to the dynamic between Jack and Karen. While Beth was concerned about their task completion, and continually monitored their task progress, Bonnie seemed to prefer engage in digressions. Although Bonnie also made contributions to their online investigations, she was increasingly ignored by Beth. For example, Beth explicitly asked Ruby to ignore Bonnie ("We can just keep going, she just keeps telling us a story all the time"):

Table 7. Middle Group's Sequence of Decisions and Arguments

	No	Desicion Types	Arguments Operations
Day 1	1	DI	C(N) CE(N)
	2	TI	C(N) D(B) CA(B)
	3	DD	C(B)
	4	TI	C(B) AW (R) CE(N) RU (R) AR (N) UA (N) UA2 (B) EA (N)
	5	TI	C (R)
	6	TI	C (B)
	7	TI	C(B) CE(B)
	8	DD	C (B) D (N, R) RU (N)
	9	TI	C (B)
	10	FT	C(B)
Day 2	11	TI	C(B) D(N)
	12	DI	C (N) D(B) CE(N)
	13	ACR	C(B) D(N) CE(N) RC(B)
	14	CON	C (R)
	15	TT	C (R)
	16	ACR	C (N) D(B)
	17	DI	C(R) D(B) RC(R)
	18	DI	C(B) CA (N) RC(B) CA (N) EA(R->N) RC (B) RC (N) EA(R->N) AR (B)
	19	TI	C(B) EA(N)
	20	DR	C(N) EA(R)
	21	FT	C (R) D(B) CE(R) EA(B) RC(R) EA(N) CA(B) EA(B)
	22	DI	C(B) D(R) RC(B) CA(R) EA(B)
	23	ACR	C(N) D(B) CE(B) EA(N)
	24	FT	C(R) D(N) RU(R) CE(R) AC(B) RC(R)
	25	ACR	C(B) CE(B) EA(R)
	26	DR	C(B)
	27	TI	
	28	TI	
	29	TI	C(N) D(B,R) CE(N) RU(B) CA(R) RC(N)
	30	DI	C(R) D(B) AW(B) CE(R) EA(B) CF(R) CA(N) EA(B) RC(R) CE(R) D(B) RC(R)
	31	TI	C(R) CE(R) D(B) RC(R)
Day 3	32	DI	C(B) CO(R) AW(B) CE(R) EA(B)
	33	DI	C(B)
	34	TI	C(R) D(B) CA(B) EA(R)
	35	TI	C(R)
	36	TI	C(B) RC(B) D(N) EA(N) CF(B)
	37	ACR	C(N) EA(B)
	38	DI	C(B) EA(R)
	39	ACR	
	40	TT	C(N) EA(B)

Beth: If there is more humidity the leaf is bigger right.
Bonnie: I feel like, we are like one of the rich school located in the Manhattan beach,
Beth: the leaf is bigger, if

Bonnie: Barbara is so cool [she is singing] the school has smart boards, it is like it like kind of like a white board. You know, the white board marker things, it's like real marker thing like is different .
Ruby: sure

Beth: we can just keep going
Ruby: Ok keep going
Beth : she just keeps telling us a story all the time

Beth also did not listen to Bonnie's opinion when Bonnie made task-related comments, and ignored her points. Although Bonnie disagreed about Beth's graph interpretation and asked her opinion about a graph line shape, Beth simply answered, "I don't know," and typed in as an answer her claim that the graphs showed similar patterns. She did not seek further explanation about why Bonnie did not agree.

Beth: this one changes more drastically
Bonnie: It doesn't deep down as much as the blue one (she pointed out a line of the graph on the screen)
Bonnie: I mean, but it is still same
Beth: It doesn't deep down to the bottom
Bonnie: but it is mostly same
Bonnie: is it up to this from bottom?
Beth: I don't know
Beth is typing the description of graph into computer with reading aloud drastically change

However, in the middle of the second day, Ruby and Bonnie both pointed out that Beth did not properly describe a graph, and thus made the wrong interpretation:

Beth: That is an exactly same thing (a new graph showed a same pattern of previously made graph)
Ruby: Oh my god, she hears (she is taking about a researcher)
Bonnie: It has, a more rapid drop at the very end
Beth: Actually, that looks exactly same, here [she pointed out a part of line on the graph
Bonnie: Yeah, but it has a rapid drop, looks very different, and look here, this one too [she pointed out parts of the graph]
Ruby: Yeah, it is different
Beth: That does not make sense
Bonnie: but still looks different
Ruby: go back to the saved graph (Beth moved back to review page and clicked a saved graph)
The three girls looked at the graph. Beth and Bonnie pointed out parts of line on the graph.
Ruby: It looks different because
Beth: Ok, it drops drops and drops. It is supposed to be ((same)), but

When Beth argued that the graph looked that same as the previous graph, Bonnie disagreed about that, and Ruby agreed with Bonnie's claim. Ruby asked Beth to show the saved previous graph and Beth finally accepted that those two graphs looked different because the latter had a rapid drop by saying "it drops, drops and drops."

Throughout the online investigation, when Beth generated graphs, she often mentioned that the graphs had similar patterns or the same look regardless of their actual shapes. She seemed to believe that graphs should show similar patterns. For example, she said, "That does not make sense," and "It is supposed to be [the same].

After Beth accepted other girls' opinion, more conflicts, especially between Beth and Ruby, became evident and the conflicts were developed into more interactive arguments. While Ruby was relatively quiet and Bonnie was ignored, their one victory seemed to encourage the two girls, especially Ruby, to challenge Beth's decisions.

Ruby challenged Beth's decision about data. As seen above, while Ruby and Bonnie seemed to want to report data "as it is," Beth seemed to adapt the data description or interpretation to report it "as it should be." The girls argued about whether they could add three graphs at the same time or not, whether the three graphs showed a similar or different pattern and relationship between the graphs (humidity) and leaf size. In addition, providing and requesting justifications such as ask warrants and cause and effects increased because the girls started asking each other why they thought what they did. For example, Beth requested a warrant and Ruby provided a reason why she thought leaf is small when the temperature high. Before then, Beth hardly requested or provided warrants. She used to accept others' opinion without asking for warrants, or – most of the time – did not listen to others' opinions and stuck to her own claim.

Beth: Where are the temperatures.. spots that shown?
Ruby: (she points out) here, area 1
Bonnie: No, it is not, area 1, it is area three. Area three.
Beth: Confused, what are you talking about?
Ruby: When is hot, the leaf size is smaller because it gets enough sun
Beth: I know what you just said

In addition to their conflicts based on different views about data, Ruby also challenged Beth's way of handling tasks. When Beth wanted to move on, Ruby said "We need to add something more" and corrected word choice that Beth made. At this time, she took the laptop from Beth and typed something by herself. While Beth typed 'transpiring', Red corrected it to 'transpiration', pointing out that transcription is a more accurate term than transpiring. In addition, when Bonnie provided comments or made a claim, Ruby were more likely to make explicit agreements about Bonnie's opinions and encouraged to her to say more.

Not only verbal conflicts, such as disagreements and criticism, but also physical signals, such as who took the laptop, became common. Because control of the laptop indicated who had the power to make a final decision to determine answers in this group, the frequency of the sequence for taking of computer was investigated to see when Beth and Ruby's conflicts were developed and prompted arguments. While there was no conflict as far as controlling the computer on the first day, the frequency of this sequence increased on the second day,

Table 8. High Group's Sequence of Decisions and Arguments

No	Desicion Types	Arguments Operations	No	Desicion Types	Arguments Operations
1			11	ACR	
2	TI	C(B) EA(A) CF(B)	12	DI	C(A) EA(B) CF(B)
3	DR	C(A) CA(B) D(A) CO(B) RC(A) EA(B)	13	DI	C(B)CA(A) CE(B) EA(A)
4	FT	C(A) EA(B) CF(A)	14	TI	C(A) D(B) RU(B) EA(A)
5	TI	C(B) D(A) RU(B) AR(A) EA(B)	15	DD	
6	DR	C(B) RC(A)	16	TI	C(B)D(A) EA(B)
7	DI	C(B) D(A) RU(B) AR(A)	17	DI	C(A) CA(B)
8	ACR		18	DI	CE (A) C(A) EA(B)
9	TI		19	FT	
10	FT	C(B) EA(A) CF(B)	20	DR	C(B) EA(A) CF(B)
			21	TI	C(B) EA(A) CF(B)

especially after Beth made incorrect points but stuck to her opinion. This happened six times on the second day and five times on the third day.

The group also made more resolutions subsequent to explicit agreements. Both Beth and Ruby said, "OK," and "Yeah," and repeated what each other just pointed out.

Beth: I see what you are talking about. The leaves are smaller when it is hotter.
Ruby: Ok, it is number three. The leaves are smaller and it is hotter.
Ruby: So, this is average
Beth: Ok. In area 2, it is not as hot as the area2, and the leaves are bigger, right
Ruby: yeah,

In summary, the student who managed their tasks and provided claims was Beth, especially for the first two days, and she often ignored Bonnie's claims or comments. The group's arguments became activated after Bonnie and Ruby made Beth accept their claim. The conflicts between Beth and Ruby contributed to make their arguments more interactive.

High achieving group

Table 8 shows chronologically arranged argument sequences and decision types of the high achieving group. This group's most frequent arguments were about data interpretation. The high achieving group argued less often (15 out of 21 decisions) and a large portion of their arguments showed a similar pattern: Claim – Explicit agreement – Confirmation. In many cases, this group's arguments were resolved through making explicit agreements.

Unlike the other two groups, this group in most cases quickly reached agreement without further questioning, disagreement or confusion. When one member did not provide any explanation for an answer, the others still seemed to understand it. While they revised and edited their answers, for example checking spellings or rephrasing sentences, the basic idea of the answers was not changed. It seems likely that they consistently understood without discussion: because they were high achievers, it is unlikely that one was simply agreeing with the others, whatever the answer, even when he did not understand. In other words, the answers to guiding questions seemed obvious to students in this group, negating the need for discussion, rather than controversial, which might have led them to further arguments.

Although the high achieving group also experienced frustration about their computer issue, the two boys rarely provide derogatory or controlling comments. Rather the members of this group tended to encourage or praise each other by often calling, "Genius," or "Good man."

In this group, there was no serious conflict and the two members seem to have equally distributed power. When Bryan answered and typed questions, Andrew also made significant contributions to their tasks because he monitored and corrected the answers through sentence completion, checking spelling errors and correcting the content of the answers. They also controlled their progress together, making explicit agreements and confirmations.

DISCUSSION

Our analyses are clearly exploratory, but they illuminate some ways that interpersonal dynamics influence collaborative argumentation.

Overall Patterns of Argument

We actually began these analyses with a sense that students were not arguing enough. What we found, however, is that students were arguing more often than not about the decisions relevant for successfully completing their investigations. The patterns we see in what groups argued about are consistent with findings from collaboration research. Before we discuss our findings, it is important to note that particular group structure of this study—gender balance and different number of members in a group (e.g. three females in the middle group vs. two males in the high group) might affect the group dynamics of collaborative argumentation. In addition, collaborative argumentation in mixed-ability groups needs to be addressed for future research to expand our understanding about the influence of group dynamics on collaborative argumentation.

The Low ability group had the least productive collaboration. They argued the least about their decisions than any of the groups we observed, and they rarely argued about the meaning of the data they were getting. Instead, they seemed confused more often than the other groups and they argued mostly about what task to do next during their investigation. Moreover, one group member, Karen, did not really collaborate with Jack or Don in a meaningful way, and the relationship between Karen and Jack was highly antagonistic. This appeared to detract from the group's ability to productively get done what they needed to get done. Mostly, the lack of substantive argumentation about data within this group suggests that these students may have been primarily concerned with getting their task done without really making sense of what they were doing.

The High group, on the other hand, appears to have collaborated at a level of productivity that one would expect. Their arguments focused mainly on how to make sense of the data they were generating in terms of the question they were trying to answer. They were highly responsive and accepting of each other's contributions. Moreover, they encouraged each other with explicit affirmations of the value of key contributions. In other words, they were a typical high achieving group according to the collaboration literature.

The Middle group stands out in a number of ways. For one thing, they argued much more than the other two groups. They argued about what to do, what their data meant, and how to use the software. Their arguments also tended to be longer than the other group's, reflecting the higher level of conflict within the group. The social relations within this group were fairly dynamic. Although Beth continually asserted dominant social status, this status was contested by Ruby and Bonnie. This contest led to many substantive arguments about their task. This is very different from the Low group, where Karen's low status within the group appeared set and she never challenged it or really seemed inclined to do so. The High group, on the other hand, seemed characterized by equal social status, thus arguments seemed easily resolved.

We can put these patterns into Barron's (2003) dual space model, as follows. The Low group could not successfully manage the relational space of their collaboration. They particularly struggled to maintain joint attention, apparently because of the open antagonism between Jack and Karen. They also struggled within the content space of the problem. Whether this is because they lacked the knowledge they needed to do so, or they just did not care, is hard to say. On the other hand, the High group easily navigated the relational space. The two boys were obviously friends, and they got along easily. They also seemed to share a content space, as their arguments were most quickly and easily resolved.

The Middle group is an interesting case. They struggled to co-construct a productive relational space early on, with Beth being very dismissive of Bonnie and Ruby not very much engaged. Yet, once Ruby became engaged they created a relational space that allowed all three of the girls to contribute their ideas to the group. This change in the relational space led to a change in the content space, as the girls generated a broader range of ideas for their collaboration. Moreover, as Beth's dominance was challenged the group became more able to correct errors; they generated better ideas through their arguments.

Cognitive and Social Conflict as Prompts to Argue

These patterns lead us to wonder what kinds of conflict might promote productive collaborative argumentation. The experience of Beth, Bonnie, and Ruby suggests that some social conflict is a good thing. In their case it led to substantive arguments that helped them pursue their collaborative task. On the other hand, the level of conflict between Jack and Karen was clearly not a good thing, and Andrew and Bryan had no real social conflict at all. We don't really know whether or not Beth, Bonnie, and Ruby are typical of other groups or not. It seems safe to say that it cannot be counted on that groups will commonly share the level of friendship between Andrew and Bryan. Rather, in most groups we should expect some level of social conflict. This might be especially true if we consider mixed-ability groups where there is likely to be wide range of conceptions about the content space and a wide range of values and interests brought to the relational space.

It seems that a relational space that makes room for power struggle is potentially productive. Bonnie and Ruby appeared to believe that they should be equal partners in the collaboration, and when Beth excluded them they eventually challenged her dominance. This reflects that they believed they could stand up to Beth, and that they cared enough about their task to do it. Karen, Jack, and Don also could have struggled over power when Jack asserted himself but they did not. Karen's reasons seems pretty clear, she seemed simply not to care very much about the outcome. That said, we cannot rule out the possibility that Karen may have felt unable to contest Jack's power; she might have been intimidated.

Our findings suggest that more attention should be paid to the social influences on student argumentation and collaboration. There are a number of questions to be answered. Are productive groups characterized by conflict? If so, how much and what kind? Would mixed-ability groups have interacted like our Middle group, or different from all of our groups? How can the collaborative task itself be structured to engender productive kinds of conflict within a group? So far, thinking on that question seems to center around cognitive conflict, but it may be that such cognitive conflicts might be productively linked to social ones. We confess that we do not really know what that might mean yet. Still, our findings show clearly that the social interactions between group members affect the structure of their arguments, and it is likely they affect argument quality as well, but the nature of these effects remains unknown.

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