Peer Scaffolding to Learn Science in Symmetrical Groups Collaborating Over Time

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Abstract: While educators often assume that students working together in symmetrical groups support each other's learning, this scaffolding may look very different from scaffolding in asymmetrical relationships. Little is known about *how* students in symmetrical groups support one another to learn. We examined scaffolding interactions of two symmetrical groups of students as they worked on physics simulations over time. We analyzed the interactions within each group to understand how students support their peers to learn science. We found that students in Group A had a significantly greater proportion of scaffolding discourse than students in Group B, but there were no significant differences in students' learning gains between the two groups. However, we found that one student in each group emerged as a more dominant scaffolder by driving the discourse and helping the group move forward with the task; this student made the most learning gains in each group.

Keywords: scaffolding, symmetrical peers, collaboration, science education

Introduction

Teachers cannot feasibly provide individual support to all of their students simultaneously in a classroom. One potential strategy to disperse the responsibility of instructing many students at the same time is to have students work together in small groups. Educators often assume that students in small groups will help each other learn (Webb, Baxter, Thompson, 1997); however, it is still unclear how support from peers affects students' learning. Can peers actually provide the necessary support to help each other learn? Evidence that peers can successfully support each other to learn together would further encourage utilizing small group work in the classroom.

Scaffolding describes the individualized support a teacher can provide to a student in order to help that student accomplish tasks that he or she would not be able to accomplish alone (Wood, Bruner, & Ross, 1976). This traditional notion of scaffolding involves an asymmetrical relationship between a student and a more capable other, often an adult teacher. Collaborative learning, however, refers to a group of students working together to learn or solve a problem; this usually involves a symmetrical group of peers who are often assumed to be of equal ability, prior knowledge, and status (Dillenbourg, 1999). While the symmetry of knowledge may shift between peers, the symmetry of status and participation is typically held constant. Scaffolding in symmetrical peer groups may therefore emerge as a mutual process in which different students scaffold at different times as symmetry of knowledge fluctuates (Sangin, Molinari, Nussli, & Dillenbourg, 2008).

Rogoff (1990) showed that there are interesting differences in the scaffolding that takes place within symmetrical versus asymmetrical relationships. We should not expect peer scaffolding to look the same as teacher-student scaffolding; the expert-novice relationship between a teacher and student is characterized by assessing the student's understanding and ability so that support can be specifically tailored to the unique needs of the student, whereas peers may not be able to assess others' needs and subsequently provide support in the same way (Rogoff, 1990). Research shows that scaffolding among equally inexperienced peers may be less explicit and intentional than teacher scaffolding, but still results in the group of peers being able to solve complex problems and complete tasks together that they could not do alone (Wells, 1999; Zuckerman, 2003). With the exception of a few examples, such as reciprocal teaching (Palinscar & Brown, 1984) and thinking together (Dawes, Mercer, & Wegerif, 2000), in which students are trained to give specific kinds of support and teachers intentionally model what scaffolding should look like in a specific context, students working in collaborative groups are usually not trained to scaffold in such an intentional way.

It is important to examine group discourse to understand whether peers play a supportive role and help each other learn. Research in computer supported collaborative learning has shown that groups who acknowledge, discuss, and build upon each other's proposals learn more than groups who ignore or reject proposals without discussion (e.g., Barron, 2003; Roschelle, 1992). Drawing from the traditional notion of scaffolding (Wood, Bruner, & Ross, 1976; Puntambekar & Kolodner, 2005), discourse including prompting peers, checking in to establish common goals and assess understanding, explaining concepts, and responding to others' questions would be indicative of quality group collaboration, which would benefit peers' learning. Thus, we approach the investigation of small group collaboration from a peer scaffolding perspective, and we hypothesize that groups of students who exhibit these types of discourse would learn more than groups of students who do not engage in these scaffolding interactions. The reciprocal nature of interactions is a key aspect of scaffolding, so it is also important to understand how individuals contribute to the group's discourse.

In the current study, we take a more in depth look into the scaffolding interactions that unfolded in two groups of 6th grade students with similar initial levels of prior knowledge working together on virtual physics simulations over a 12-week period. We aim to answer the question: How do symmetrical peers, working together in small groups, provide the support necessary to help each other learn science? To address this question, we first examined students' discourse to determine the types of interactions indicative of scaffolding among peers and how individuals contribute to these interactions. We also analyzed how these scaffolding interactions might relate to students' learning.

Methods

Participants and instructional context

We examined two groups (Group A and Group B) of four 6th grade students in their science classroom as they worked together during a physics unit. The students attended a US Midwestern public school located in a mid-sized city. The two groups of students were from the same science class, with a total of 27 students, taught by a teacher with three years of experience implementing the CoMPASS curriculum used in this study. We chose these groups for analysis based on the similarities in individual students' initial scores within the groups on a pretest of physics knowledge, since comparable prior knowledge is an important characteristic of symmetrical peers. We focused on using prior knowledge to define peers as symmetrical given the availability of this data.

The unit was a 12-week design-based curriculum in which students learned the physics concepts of forces, motion, work, and energy through investigating how to design a roller coaster. This curriculum relied heavily on the students driving their own learning through conducting experiments and research in small groups, instead of the teacher being the predominant source of information. The groups had autonomy to make decisions about experiments related to four major sections of their roller coasters (the car lift, the initial drop, hills, and stopping the car), and the students worked together to draw conclusions from these experiments in order to understand the physics behind their roller coaster design. Each small group worked together on one computer to participate in a total of nine simulated experiments addressing the different sections of their roller coaster. The student-centered and inquiry-based nature of this curriculum provided a rich context to investigate how students support each other to learn because learning outcomes would largely relate to the learning that occurred during group work, as opposed to information students might learn directly from the teacher.

Data sources and analysis

Pre- and posttest measures

The students were given a physics content knowledge test before beginning the unit to assess their prior knowledge and again after completing the unit to assess their learning gains. The test consisted of 29 multiple-choice questions addressing the physics concepts and relationships that the roller coaster unit was designed to teach. Each correct answer earned one point and incorrect answers earned zero points. Content validity of the test was established by consulting with physics experts. Groups A and B were chosen as the participants of this study based on the similarities of their physics pretest scores; the students in Group A had individual scores of 16, 17, 18, and 19 and students in Group B had individual scores of 14, 15, 15, and 16. We thus concluded that the students within the groups were symmetrical in that they had similar levels of initial physics knowledge.

Analysis of group discourse

The discourse within Group A and Group B was analyzed in order to investigate whether interactions to support the group's learning took place. We selected four videos of each group conducting virtual simulation experiments over the course of the unit; we selected the first video from each of the four sections of the unit to ensure the groups were completing the same activities and to capture students' discourse over multiple weeks. One group member from Group B was absent for the car lift simulation, so the remaining three simulations were used for analysis, resulting in six videos in total, three for each group, occurring over a span of four weeks.

The videos were transcribed, and we segmented the transcripts into lines based on turns of talk. We first qualitatively characterized the interactions among students in the two groups from the videos. We then quantified these interactions by coding each turn of talk for both the "content of talk" (what students were talking about) and the "role of talk" (what contribution the statements were making to the group). Descriptions and examples of codes are shown in Table 1.

The “content of talk” codes were developed based on our observations of what students talked about, including: a) science, b) metacognitive, c) procedural, d) off task, and e) not applicable content. We identified the codes of science and metacognitive talk (italicized in Table 1) as being beneficial interactions for learning, since students would need to engage in science related and reflective talk to develop conceptual understanding.

The “role of talk” codes were first developed based on the theories of learning through scaffolding discussed previously, including (italicized in Table 1): i) prompting collaboration for knowledge building, ii) checking in, iii) explaining, and iv) responding. Additional codes were later developed based on our observations of the data in order to further characterize the interactions among students, including: v) seeking help, vi) managing, vii) arguing, viii) reporting, and ix) not applicable role.

Each turn of talk could be assigned multiple codes. Since the context in which a turn of talk occurred was important in understanding the content of and type of talk that occurred, the discourse occurring before and after a particular turn of talk were taken into consideration in assigning codes. Inter-rater reliability was computed using Kappa; the first and second authors coded 15% of the transcripts, resulting in substantial agreement (Stemler, 2001) overall (K = 0.69) and on all but two individual codes—seeking help and responding. Discrepancies were resolved and the first author coded the remaining transcripts.

Table 1: Coding categories for examining student interactions during simulations

Code	Description	Examples
Content of talk:		
Science	Using science terms and / or discussing science concepts, definitions, and relationships	“If the height of the car increases, the work, required, will increase”
Metacognitive	Reflective statements that show a higher level of thinking or awareness about what is happening	“Okay, can we re-do trial 4? 'Cause I feel like my data was un-accurate.”
Procedural	Discussing how to accomplish tasks or making decisions about simulations without discussing science content	“Well we have to write this down. Wait we need to record the beginning.”
Off task	Discussing topics unrelated to science or the simulation	“No I think we need more flutes and clarinets and less trumpets”
Not applicable content	It is unclear what students are talking about	“So basically, so…,” (unintelligible)
Role of talk:		
Prompting collaboration	Seeking involvement of others; posing questions / statements to prompt group to work together to build knowledge	“So what are we gonna make the applied force, guys?”
Checking in	Inquiring if others understand the task and current plan or asking others to repeat something.	“Does everyone agree on that? “
Explaining	Describing science concepts or relationships to other group members.	“Like, as the height increases so does the distance. In order to keep it at the same angle.”
Responding	Answering questions posed by other group members.	“Yeah I had to raise the increments too
Seeking help	Explicitly asking others for help and explanation, or stating confusion.	“What do you write? I don’t know what this means.”
Managing	Giving orders, telling others what to do, bringing others back to focus	“Write it down quick! Write it down quick quick quick!”
Arguing	Bickering, argumentative, rude, or confrontational talk.	“You’re a control freak.”
Reporting	Providing surface observations or interpretations of data, opinions without justification and/or support for predictions.	“Acceleration is 9.15.”
Not applicable role	Unfinished or unclear statements, filler speech, off task talk not considered to be arguing, or repeating others’ statements.	“Yeah,” “Okay,” (unintelligible)

Average interrater reliability: K = .69. Italics denote codes related to scaffolding and beneficial peer interactions for learning.

Findings

Quantitative analysis of differences in discourse between group A and group B

To examine the nature of interactions in the two groups, we quantitatively analyzed the overall discourse by the total proportion of talk in each category. We divided the frequency (shown in parentheses in Table 2) of each type of talk over all three simulations by the total turns of talk for each group. We then conducted a test of homogeneity of proportions comparing the total proportions of talk in each category across all three simulations, as shown in Table 2, to evaluate whether there were statistical differences in the discourse present between Group A and Group B. We were specifically interested in whether the students in Group A exhibited more discourse related to scaffolding and beneficial interactions for learning science than Group B and whether Group B exhibited more off task and arguing discourse than Group A. We compared the two groups on all 14 categories and thus used the Bonferroni correction resulting in an alpha of .0036 for each comparison.

Table 2: Proportions (and frequencies) of talk across all three simulations and between group comparisons.

Type of talk		Group A	Group B	Z score
Content of talk	*Science*	0.04 (28)	0.00 (3)	4.67*
	Metacognitive	0.02 (15)	0.00 (1)	3.58*
	Procedural	0.59 (463)	0.49 (427)	4.22*
	Off task	0.11 (85)	0.33 (289)	-11.43*
	Not applicable content	0.21 (164)	0.18 (161)	1.30
Role of talk	*Prompting collaboration*	0.07 (54)	0.02 (18)	4.72*
	Checking in	0.12 (98)	0.10 (90)	1.42
	Explaining	0.02 (19)	0.01 (8)	2.37
	Responding	0.10 (77)	0.05 (45)	3.61*
	Seeking help	0.01 (6)	0.01 (9)	-0.57
	Managing	0.13 (102)	0.16 (140)	-1.72
	Arguing	0.03 (22)	0.11 (95)	-6.67*
	Reporting	0.21 (162)	0.13 (114)	4.12*
	Not applicable role	0.34 (268)	0.48 (423)	-5.90*

Italics denote types of talk we associate with scaffolding and beneficial interactions for learning. * $p < .0036$, significance level based on the Bonferroni correction for multiple comparison.

Group A showed significantly more science and metacognitive talk (both of which we associate to be beneficial for learning science) and significantly more scaffolding related talk of prompting collaboration and responding. Group A additionally showed significantly more procedural talk and reporting than Group B. In contrast, Group B showed significantly more off task talk and arguing.

Individual contributions to group's scaffolding discourse

To better understand the interactions indicative of scaffolding among peers, we took a more in depth look at individual students' discourse. Taking an individual perspective on each student's contribution to the group discourse allowed us to see the role each student played in the scaffolding interactions. We looked at the total frequency that individual students in Group A (Ravi, Anna, Owen, and Violet) and Group B (Henry, Ron, Silverio, and Max) engaged in each type of talk. Figure 1 shows the number of times individual students in Group A exhibited each type of talk. Most noticeably, Ravi contributed the most to Group A and engaged in the most prompting collaboration, checking in, and responding - all indicative of helping collaboration among group members. He also engaged in the most procedural talk and reporting so the group could complete their task.

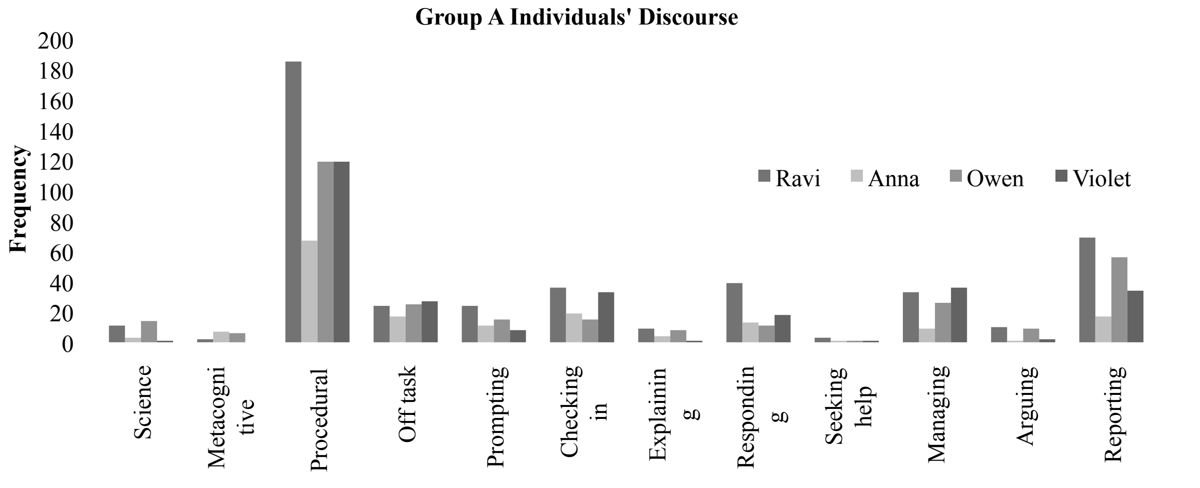

Figure 1. Group A individual students' contribution to group discourse

Figure 2 shows the number of times individual students in Group B exhibited each type of talk. Silverio contributed the most to Group B's discourse and exhibited most incidents of prompting collaboration, explaining, and responding, which are again indicative of helping group collaboration. He also engaged in the most procedural talk, managing, and reporting in order to move the group towards completing their experiments.

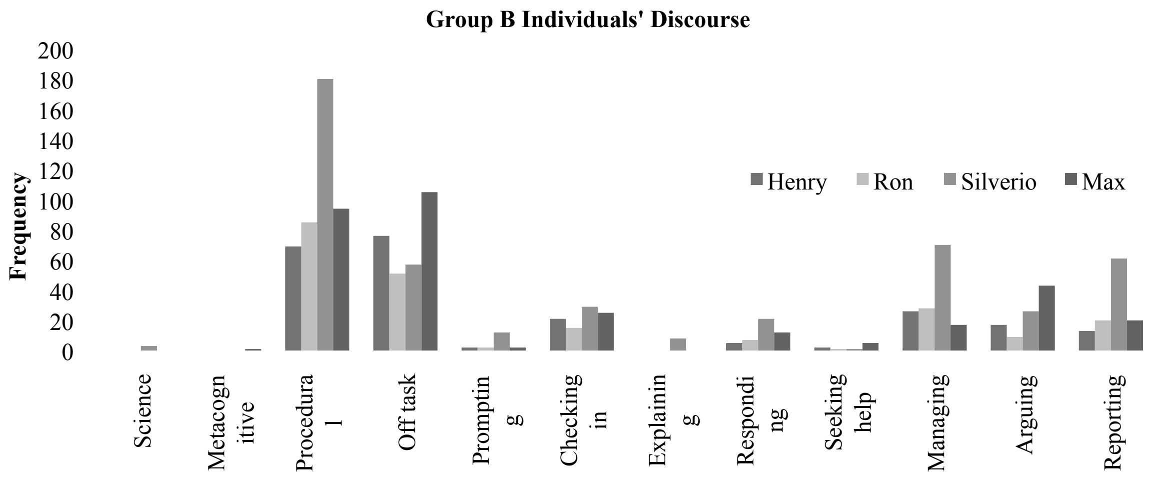

Figure 2. Group B individual students' contribution to group discourse

We also summed each student's total frequency of talk related to scaffolding and beneficial interactions for learning (the codes italicized in Table 2) and divided by the total number of scaffolding and learning discourse of the group. This analysis revealed that Ravi emerged as having the highest proportion of talk beneficial and supportive to learning in Group A at 0.42, compared to Anna at 0.20, Owen at 0.24, and Violet at 0.21. In Group B, Silverio had the highest proportion of this talk at 0.44, compared to Henry at 0.17, Ron at 0.15, and Max at 0.24. These findings show that Ravi (Group A) and Silverio (Group B) were the predominant scaffolders in their respective groups. It is important to note here that while both groups had more capable students emerge as the dominant scaffolders, these more capable students had quite different styles of interacting with their peers. We conducted a test of homogeneity of proportions to compare Ravi and Silverio's talk. We found that Ravi engaged in a significantly more science talk, $z = 2.24$, $p < .05$; promoting collaboration, $z = 2.22$, $p < .05$; and responding $z = 2.67$, $p < .01$, than Silverio. We also found that Silverio engaged in a significantly more off task talk, $z = -3.83$, $p < .01$; managing, $z = -3.87$, $p < .01$; and arguing, $z = -2.65$, $p < .01$, than Ravi.

Qualitative description of peer interactions in group A and group B

To further exhibit the differences between the groups' discourse and interactions reported above, we identified examples typical of each groups' talk and provided a qualitative description to further illustrate the peer interactions in Group A and Group B. In Group A, all of the students generally worked together to solve problems during all three simulations. They stayed focused on the simulation experiments, discussed science concepts and relationships, prompted one another to collaborate, explained science concepts and relationships, and responded to each other's questions. Ravi more frequently attempted to scaffold his peers than other group members did, and he drove the group's discourse towards a conceptual focus by prompting his peers to work together to understand what was happening in their simulation experiments.

The following transcript excerpt shows an example of how the students in Group A were engaged in trying to understand science concepts and relationships during the virtual simulation experiments, worked together in a collaborative and non-argumentative manner, and checked in with and responded to one another.

1: Anna	I wanna like - not the lift. I just wanna see, I wanna see like how fast it'll go if it does add friction because I'm just extremely curious. Ohh okay.
2: Ravi	Whoa the last, this, okay. Can we run the last trial again? With no friction, and, what, that's freaky.
3: Ravi	Okay, can we re-do trial 4? 'Cause I feel like my data was un-accurate. Okay look at this though. As it goes up .2, this one's around 2. This one's .8, it goes up .8. Now this one is around 3 and 4, it went up 6. And this one, went up, this

is about .4, it went up 5...

4: Anna	Want me to play it?
5: Violet	Well I'm just gonna keep it in case...
6: Ravi	It's inaccurate.
7: Anna	Guys can I?
8: Violet	Sure.
9: Anna	Kay it's, uh oh, sorry. The last three, 3.96.
10: Ravi	Okay, put um, the lift height maximum, oh you can just. And put like, half friction.
11: Anna	Oh wait, the initial drop correct?
12: Ravi	Uh huh, yeah.
13: Anna	Okay and I don't think that it'll work. 'Cause I tried...
14: Ravi	No still?
15: Anna	See, it, it stops, but maybe if we add the uh, friction to the cart...
16: Ravi	Oh my god. hahaha.
17: Anna	It'll just stop. I wonder what would happen if-

This excerpt shows an example of how Ravi guided the group, specifically in lines 2 and 3, to think about the physics relationships the group is experimenting with in the simulations and engaged in metacognitive talk (lines 3 and 6). This example also shows Anna and Ravi collaborating and responding to one another to better understand what was happening in their simulation.

In contrast, Group B's interactions were less productive overall and more focused on completing assignments. These students were frequently off task, argued with each other, and rarely attempted to scaffold each other. Their discussions about the simulations were procedural and focused mainly on task completion, as opposed to trying to understand the physics. Silverio noticeably took charge and managed the group by telling others what to do, making sure they were recording answers, and doing most of the work for the group. While Silverio seemed to be the most engaged with the simulation experiments and to have the best understanding of what was happening, he rarely attempted to support his peers by prompting them to collaborate and explaining science ideas.

The transcript excerpt below shows Group B's focus on task completion instead of conceptual understanding; it also exemplifies Silverio's characteristic managing style as he repeatedly tells his peers to write the answers down.

1: Silverio	Okay guys, start getting this stuff down. 5.9...
2: Ron	Where's my pencil?
3: Henry	The lord took it.
4: Silverio	Guys! Get this down or I'll just hit start and I wont...
5: Ron	Wait! I don't know where my pencil went
6: Silverio	Quick quick quick!
7: Max	Write it down quick! Write it down quick quick quick!
8: Silverio	I'm gonna hit it.

Silverio was clearly not concerned if his peers understood the answers they were writing; he simply wanted them to "get this down" so he could move on and run the next simulation experiment. Additionally, Henry's comment in line 3 provided a glimpse into the typical irrelevant and off task comments that were repeatedly made by this group. A second excerpt from Group B (below) further shows the characteristic arguing and managing interactions of this group.

1: Ron	The maximum acceleration... Guys we need the maximum acceleration.
2: Silverio	It's right there. Meoow
3: Max	What the heck. This makes no sense.
4: Silverio	It makes ton of sense! What're you looking for? What're you looking for?
5: Max	Move. Maximum acceleration...
6: Silverio	It's right there! I just pointed at it. For the fifth time I'm done pointing it out.
7: Max	((inaudible talking, grumbling)) Stop speaking Japanese!
8: Silverio	You stop speaking Japanese!

In this excerpt, Max and Silverio both used argumentative and frustrated tones. Line 6 shows Silverio's unwillingness to help Max further, even though Max was still confused. This was a missed opportunity for Silverio and the other group members to provide support and help Max learn.

Analysis of learning gains

We initially hypothesized that groups of students who engaged in more talk related to scaffolding and in more science and metacognitive talk would learn more than students who engaged in less of these types of talk. Following our findings from quantitative analyses and qualitative observations of the interactions between peers in Group A and Group B, we thus hypothesized that Group A would have learned more than Group B over the course of the physics unit. It is important to remember that the students started with similar physics prior knowledge, so learning gains are not attributed to differences in prior knowledge.

To compare the learning gains between the students in Group A (N=4) to those in Group B (N=4), we conducted an independent samples Mann-Whitney U test. Learning gains were calculated by dividing each student's actual gain between the physics pre- and posttest by the total possible gains that each student could have made. Calculating learning gains in this way, based on percentages as opposed to raw score differences, presents students' learning in terms of the amount they could have learn. The results of the test were not significant, $z = -1.16$, $p = .25$. Thus, there was no significant difference in the learning gains made by students in Group A versus Group B, despite clear differences in their discourse during the unit.

Further examination of the individual students' learning gains (reported in Table 3) showed that Ravi (Group A) and Silverio (Group B) made the largest gains in their respective groups. Thus, while there was no significant difference in overall learning gains between the students in Group A and Group B, the student in each group who contributed the most to the scaffolding discourse learned more than his respective peers.

Table 3: Individual students' learning gains

Group	Student	Pretest	Posttest	Learning gain
A	Ravi	18	21	27.27%
	Anna	19	19	0.00%
	Owen	16	19	23.08%
	Violet	17	12	-41.67%
B	Henry	14	17	20.00%
	Ron	15	19	28.57%
	Silverio	16	24	61.54%
	Max	15	17	14.29%

Discussion and implications

Educators often utilize small group work with the assumption that students will support and help each other learn, alleviating the teacher's struggle to simultaneously address many individual students' issues (Webb et al., 1997). However, the interactions that occur in a group and the ways in which peers support each other are different from teacher-student scaffolding. The goal of this paper was to better understand how students working together in symmetrical groups of peers support each other to learn. We specifically investigated 1) how the students in two different groups engaged in the types of talk we identified as related to scaffolding and beneficial to learning and 2) whether the presence of these types of talk related to students' learning over the course of the physics unit.

We found striking differences in how the students in our two groups interacted with each other. While Group A appeared to collaboratively work together and help their peers by prompting one another, responding to questions, and checking in with each other, Group B rarely appeared to support one another's learning. The students in Group A often focused on the physics content and discussed the science concepts and relationships behind the simulations, whereas the students in Group B frequently argued with each other and were often off task.

However, the most striking difference we found was that a more capable student emerged in both groups, contributing the most to and driving the discourse – but the ways in which this more capable student interacted with and supported their peers looked quite different. While the more capable student who emerged in Group A (Ravi) most frequently attempted to support his peers and guide the group towards understanding the physics concepts and relationships, the student who emerged in Group B (Silverio) frequently gave orders to his peers and was mainly concerned that the group completed the task at hand. Both Ravi and Silverio offered support, but their support differed in line with their groups' overall discourse patterns with one student giving support for collaboration and conceptual understanding while the other gave support for completing tasks and staying focused.

Even though members in Group A worked collaboratively, their learning gains were not significantly greater than those of students in Group B. The findings in this study seem to contrast Barron's (2003) findings that the quality of group collaboration has important influences on student learning. Barron showed that groups in which students acknowledge, discuss, and build on others' ideas (similar to Group A) learn more than students who ignore or reject others' proposals (similar to Group B). However, what we found was that the student in both groups who acted as the "scaffolder" by driving the discourse and helping the group move forward with the task showed the most learning gains (see Table 3). This brings up interesting issues about how we can help group members support each other and about the interactions between the more capable peer and other group members. Despite the potential of having a more capable peer in small a group to support other group members, our results show that students may lack the intention (Wells, 1999; Zuckerman, 2003) or ability (Rogoff, 1990) to scaffold and help their peers learn. Students may rarely attempt to scaffold or support their peers, as seen in Group B, or students may not be able to provide the appropriate support needed to help their peers learn, as seen in Group A. In future work, we aim to better understand the interplay between scaffolding and collaboration, specifically helping group members *support* each other, in addition to providing them with guidance for better collaboration (e.g., Mercer & Littleton, 2007). We also aim to better understand the role that collaborative interactions play in learning and how the teacher might complement those interactions to foster learning of all group members.

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