AN ABSTRACT OF THE THESIS OF

Jennifer A. Roth for the degree of Master of Science in Physics presented on December 7, 2010.
Title: Small Group Discussions in Large Lecture: Connections between Teacher Facilitation and Student Participation.

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An investigation was made to determine teacher facilitation techniques in large lecture physics classrooms that foster small group discussion. Video recordings of an introductory calculus-based physics class were taken for the 2008-2009 academic year at Oregon State University. These videos were analyzed to determine student participation in small group discussion (active, mix, or passive) during episodes when the instructor allowed students to work together. 72 video episodes were coded independently by two researchers. 24 of the 72 video episodes were selected for a more detailed analysis, including the analysis of transcriptions of these activities. Several instructor facilitation techniques that may foster or inhibit participation in small group discussion were identified from these analyses.

Small Group Discussions in Large Lecture: Connections between Teacher Facilitation and Student Participation

by

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Jennifer A. Roth, Author

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Chapter 1 – Introduction

1.1—Personal Motivation

Meaningful student discussions about science rarely happen by chance, at least not from my experience as both a teacher and student of physics at the university level. Students often expect me to present information to them with the occasional opportunity for them to ask questions and listen to me explain more information. Why should I expect any differently? From my experience as a student, this rather authoritative approach to science teaching seems to be a common pattern of instruction. Furthermore, in my formal education it was rare (if ever) that discussion or scientific argumentation was cast as a meaningful scientific skill or an effective learning method for increasing conceptual understanding. However, even when I tell my students on the first day of class that I expect them to work together, I expect them to take an active role in learning physics, and I expect these interactions will benefit their learning, group discussion time often turns into silent individual problem-solving (or individual off-task activity) time.

1.2—Research Questions

The main question that arises is this: what can an instructor do to foster scientific interactions in the classroom? More specifically, this research is guided by the following subset of related questions:

1. How does student participation (whether or not they participate in peer discussion, and for how long) in small group discussion activities change over the course of an academic term and over the course of an academic year?

2. Are there changes in instructor facilitation of activities that may correlate with observed changes in student participation?

3. In what ways does the timing of an activity correlate with student participation in discussion during the activity?

4. How do instructor statements made before an activity, during the introduction to an activity, and during the small group discussion portion of an activity correlate with student participation in discussion?

5. Do trends in the amount of student reasoning heard by the teacher and entire class correlate with trends in student participation in discussion?

By reviewing data from small group discussion activities in a large-enrollment university physics course, an attempt is made to answer these questions.

1.3—Thesis Overview

Chapter 2 contains a brief review of literature addressing argumentation in science, benefits of student discussion in the science classroom, and teacher facilitation of scientific discourse. The methods of data collection and video analysis used for this research are expounded in Chapter 3. The results from the analysis of 72 video episodes are discussed in Chapter 4. The transcriptions of a set of 24 of these 72 episodes were analyzed to identify possible correlations between teacher facilitation and student participation, as discussed in Chapter 5. Chapter 6 details four case studies comparing teacher facilitation and student participation for identical problems/activities in two different lecture sections. Conclusions and directions for future research are discussed in Chapter 7.

Chapter 2—Literature Review

2.1—Social Interaction and the Nature of Science

A scientist needs to have a thorough understanding of the currently accepted theories, postulates, and methods of the discipline, but this alone is not sufficient to understand and perform science. Scientific theories develop and evolve as researchers gather evidence and analyze their observations. This process is rarely a solitary one. By nature, science is a complex social process [1, 2]. Colleagues or peers almost always play a role in the design, execution, analysis, presentation, and/or review of scientific research. Different people bring a variety of perspectives to a research group or field and can identify shortcomings, new interpretations, or unique patterns that a single scientist would be unable to produce alone [1]. Thus, to be successful as a scientist, one must be capable of collaborating with others and effectively communicating ideas.

Scientists must also be capable of forming arguments based on evidence, since, by the nature of the discipline, scientific claims must ultimately be based on physical evidence instead of an appeal to authority [1]. Although published scientific documents generally follow a straightforward analytical line of reasoning, the argumentation strategies employed during the day-to-day interactions within a research group can be less formal and more subtle [3]. These strategies, known as "dialectical" and "rhetorical" argumentation, are prevalent in the development of more formal, "analytical" arguments [3]. They occur during debate or discussion, and are generally more oratorical than the strategies employed in a formal research paper [3]. Without social interaction, the dialectical and rhetorical argumentation critical to developing analytical arguments could not occur. Clearly, collaborative discourse and argumentation are fundamental to science.

2.2—Positive Effects of Scientific Discourse in the Classroom

It follows that learning to form and defend scientific arguments is an essential part of learning science. As Osborne argues in his recent review, since "all scientists must subject their ideas to the scrutiny of their peers," science students must learn to do the same [2]. This view aligns with the National Science Education Standards, which call for more emphasis on "science as argument and explanation," and "communicating science explanations." [4].

A growing body of evidence suggests that peer discussion can improve students' conceptual understanding of science. A study conducted at the University of Minnesota in an introductory algebra-based physics course demonstrates the value of group discussion, particularly in problem solving [5]. Students were taught an expert-like problem solving strategy and assigned to mixed-ability groups for problem solving. The authors found that a better solution was produced by groups than was produced by any of the individuals in the group on a matched individual problem. Students in this section also exhibited more expert-like problem solving techniques than students in a traditional control course, although this result could be attributed to the effects of group discussion, the problem solving intervention, or both.

Hake's 1998 study of 62 introductory physics courses examined students' normalized gains on concept tests, either the Halloun-Hestenes Mechanics Diagnostic or the Force Concept Inventory [6]. He examined classrooms that employed "interactive engagement" techniques and traditional classrooms that did not employ such techniques. Interactive engagement methods included "heads-on and hands-on activities which yield[ed] immediate feedback through discussion with peers and/or instructors" [6]. Students in the traditional classrooms had an average normalized gain of 0.23 +/- 0.04, while students in the interactive engagement settings had an average gain of 0.48 +/- 0.14. This finding suggests that gains in conceptual understanding of physics are higher when student discussion is incorporated over the course of a term.

One widely-used interactive engagement method is Peer Instruction (PI), developed by Eric Mazur at Harvard University [7]. PI has been used effectively in large lecture university settings as well as in smaller high school and community college classrooms. It involves devoting a portion of the science class period to

"ConcepTests" [7]. This involves posing a question, which generally takes up to about a minute. The next 1-2 minutes are allotted for students to individually work on the question and report their answers. Often answers are reported using an electronic audience response system (also called a "clicker" or "voting" system.) Then 2-4 minutes are given for discussion with peers, and for recasting their vote or answer. Finally, the class discusses the answer to the question together, often with students sharing their explanations. Results from over ten years of data collected from Harvard physics classrooms incorporating PI indicate that this strategy improves student conceptual reasoning and quantitative problem solving [7]. Survey data from almost 400 instructors at other institutions incorporating PI tend to show conceptual gains at the level of classrooms using interactive engagement techniques [7].

Social interactions have also been shown to improve conceptual understanding on a day-to-day basis. Henriksen and Angell analyzed audio recordings of small groups discussing clicker or voting questions during the lecture section of a Norwegian university introductory physics class [8]. They found that although discussion often proceeded in a haphazard fashion, groups were sometimes able to come eventually to a physically correct solution, suggesting that students were able to gain understanding through the process of discussion.

Smith and Wood also studied student responses to clicker questions, but in this case in the context of a university biology classroom [9]. The instructor would pose a question and allow individual responses. Then he would give time for group discussion and a second response to the same question. Finally, a second isomorphic question, or question covering a similar concept with a different cover story, was posed to which students responded individually. This pattern of questioning occurred over the course of the term. Not only did the scores on the first question improve after peer discussion, but results on the second question were also higher than the scores on the initial individual response. The authors showed through statistical analysis of the questioning data that some of the students who improved their performance after peer discussion must have come from groups where no student originally answered the first question correctly. The fact that even these naïve groups could arrive at the correct answer and then carry their understanding over to a new question suggested a constructivist explanation: that students gained understanding through the process of discussion.

Andre, an instructor at Ohio State University, found that students recognized several of the benefits of group discussion that are supported by research [10]. By reviewing student e-mail feedback and anonymous journal entries at the end of the quarter, Andre was able to get a feel for what students thought of their physics course, which relied heavily on group discussion during lecture, recitation, and lab. Students agreed with several findings from education research: that group discussion results in a deeper understanding than listening to a lecture, that “time spent verbalizing is a key factor in this experience," and that they could solve harder problems as a group than any one of them could solve alone [10].

Although there is mounting evidence that discussion-based, or dialogic, discourse is a necessary part of the science classroom, it should be noted that authoritative discourse is also crucial [11]. Employing dialogic discourse is effective for accomplishing certain teaching goals, including eliciting students' ideas and conceptions. If a teacher's aim is to make explicit the science perspective, which Mortimer and Scott argue is an essential aspect of teaching science, authoritative discourse would likely be more effective [11]. Mortimer and Scott argue that science lessons must include a tension between authoritative and dialogic interactions in order for students to come to a full disciplinary understanding of science [11].

2.3—Fostering Discussion in the Science Classroom

Knowing that discussion and social interaction are critical to learning science and actually facilitating scientific discourse among students are two very different things. What can an instructor do to promote productive student discussion in the classroom?

To the extent he or she has control over the physical arrangement of the classroom an instructor can start to create an environment that fosters discussion. The physical positioning of students within a classroom has been shown to affect the level of peer interaction and engagement [12]. Heller and Hollabaugh studied group problem solving in introductory physics recitations at the University of Minnesota and in modern physics classes at Normandale Community College [12]. They found that when groups of three were seated side-by-side, one member was off-task or working in isolation. However, when students in a group were facing one another, this did not occur. Thus arranging the chairs, tables, desks, and other physical features of a classroom can either discourage or promote student interactions. The same study by Heller also demonstrated that the type of question posed affected the level of participation [12]. Context-rich problems were defined as problems that required the use of conceptual understanding of physics to "qualitatively analyze a problem before… [manipulating] equations." [12] These problems were designed to mimic real-world problems. Questions that were context-rich "forced the groups to discuss physics issues while practicing effective problem-solving techniques." [12]

Researchers in Toronto compared a modified Peer Instruction technique to an intervention known as "Collaborative Groups" (CG) [13]. This type of activity involves a statement of the problem on a PowerPoint Slide and on a group handout. Groups of 3-5 students work on the problem for about 7 minutes; each student in the group is assigned a role to play. During this time, the instructor circulates the room and chooses a few groups to present to the class, possibly groups with different answers or strategies. The selected groups then present to the class for the next 2-4 minutes, followed by a whole-class question and answer period of about 3 minutes. Then the class is given 2 minutes to vote using clickers. Finally the instructor explains the answer to the problem by showing the class a demonstration, either on video or using available equipment.

This intervention was used to teach two concepts in lecture section A, while Modified Peer Instruction (MPI) was used to teach these same concepts in lecture section B. Two other concepts were taught to classroom B using CG, and these same concepts were taught to classroom A using MPI. Two instructors facilitated these activities. Each facilitated one MPI and one CG activity in each classroom. Final exam questions tested three of these concepts, and results were analyzed to determine the effectiveness of the two strategies. In all three cases, the classroom who participated in the CG intervention had a higher average on the corresponding exam question, than the classroom who took part in the MPI intervention; in two of the cases, the difference in average scores was statistically significant [13]. This suggests that the CG method was more effective at enhancing student understanding than the MPI method. The authors note, however, that MPI is more practical in terms of the class time devoted to the activity and the ease of grading. It is still a valuable tool for short, discussion-based classroom interventions.

In their recent study mentioned earlier, Henriksen and Angell found that using a voting system provided a stimulus and incentive for group discussion of physics [8].

They also commented, after reviewing the audio recordings of small groups discussing Peer Instruction questions, that “students and lecturers might benefit from expanding their view of teaching and learning to include the sociocultural perspective” [8]. Perhaps if teachers and students understood the social nature of learning and the benefits of social interaction, they would be more willing to incorporate discussion activities into their lesson plans or to participate in group discussion.

Recent work by Pollock and Finkelstein supports the idea that lecturers benefit from an awareness of current Physics Education Research (PER) [14]. They examined physics classes taught by instructors with varying levels of familiarity with PER. Of the six instructors studied, they found that classes taught or co-taught by PER faculty had the highest learning gains, classes taught by instructors that were well-informed of PER had the next highest learning gains, and classes taught by traditional instructors who were not well aware of PER had the lowest learning gains. This suggests that greater instructor familiarity with current education research enhances the types of classroom interactions that improve conceptual understanding.

While studying a reformed upper division undergraduate physics course, Meyer found that students neglected to work together until prompted, even though they had been working in groups for several previous activities [15]. This suggests that explicitly. Meyer also found that weaker students preferred lecturing prior to an exercise, and that the lecturer felt students would be less likely to be discouraged on a difficult activity if they knew what to expect in terms of difficulty, and if they had a brief explanation of the motivation behind the activity.

Further insight into promoting scientific discourse in the classroom can be gained from examining the practices of practitioners who have successfully facilitated student discussion of science in the classroom. In an anecdotal, transcript-based study of her own classroom, Pieczura found several techniques to be effective at promoting scientific argumentation within her fourth-grade classroom [16]. A necessary condition for successful student participation in argumentation was exposing students to a risk-free environment. Pieczura accomplished this through guided classroom activities, modeling argumentation, and discussions of how to argue respectfully. Encouraging students to question and allowing them to design experiments to answer those questions was also beneficial in promoting argumentation.

Jim Minstrell, another effective facilitator of student discussion, used what is termed "reflective discourse" in his high school physics classroom [17]. This type of discourse is characterized by a) "students [expressing] their own thoughts", b) "teacher and…students [engaging] in extended series of questioning exchanges that help students articulate their beliefs", and c) "student/student exchanges [that] involve one student trying to understand the thinking of another" [17]. Through in-class observations, and careful review of video taken in Minstrell's classroom, vanZee noted several characteristics of reflective discourse that may provide insight into how to promote scientific discourse in any classroom. For instance, Minstrell often made statements that constructed identities for his students as active learners or "sensemakers" [17]. He viewed his role as one of negotiating ideas with students until the classroom reached a shared understanding and refrained from simply transmitting information. Often Minstrell would follow the students' lead in reasoning by responding to students with neutral (rather than evaluative) statements, by asking questions to further elicit student ideas, by treating students as conversational partners, and by allowing periods of silence to encourage student thinking. These techniques are likely beneficial in promoting appropriate discourse in any science classroom.

In line with Minstrell's philosophy, Schiller and Joseph also claim from their experience in the classroom and in training pre-service teachers, that in order to facilitate understanding, the teacher must elicit what students are really thinking [18]. They stress through their tetrahedral model of classroom discourse that the teacher not always be the leader of a discussion—students can also take a lead. In order to create an environment where this type of classroom discussion thrives, teachers must develop relationships of trust and respect with their students, such that students know the teacher is there to help them learn, not to try to catch them off-guard or embarrass them. Giving students a chance to work in small groups before defending their ideas in front of the class helps students develop scientific argumentation skills. In large class discussions, Schiller and Joseph also advocate a longer wait time before calling on a student to respond, as it gives the students time to process the question, and allows the teacher to call on someone other than the student who always has his or her hand in the air first.

Turpen and Finkelstein also noted several techniques or practices that may be beneficial for promoting student discussion [19]. By analyzing the practices of six physics instructors teaching large-enrollment undergraduate physics courses, Turpen and Finkelstein were able to determine several dimensions of practice that may affect the participation in and learning gains from the use of clicker questions. Given their observations in class, through instructor interviews, and in student responses to clicker questions, They noted that there were large discrepancies from instructor to instructor in the opportunities provided to students to participate in practices 5 through 10. This raises the question of whether providing these opportunities to students affects participation in small group discussion or influences student performance in other areas.

From her study of eighty sixth-grade students and their life science teacher, Bianchini was able to determine the effectiveness of certain strategies in promoting equitable discourse amongst students working in small groups [20]. Productive, equitable group work is more likely to occur when the instructor makes an effort to assign competence to low status students and to articulate the multiple abilities of different students might bring to a group. She suggests that activities or tasks be designed to promote interdependence of group members, while at the same time holding each student individually accountable for learning. Additionally, students will be more likely to engage in meaningful scientific discussion if they have a more complete understanding of science as a field where argumentation is fundamental.

Chapter 3—Methods

3.1—Setting

The setting of this study was an introductory calculus-based physics sequence of courses taught at Oregon State University from September 2008 to June 2009. The sequence spanned three courses taught over three successive 10-week terms or quarters: Physics 211 during Fall 2008, Physics 212 during Winter 2009, and Physics 213 during Spring 2009. All three courses were taught by an instructor with physics education research background and two years' experience teaching in interactive engagement classrooms, one of which was at Oregon State University.

The class was split into two lecture sections, each of which met for 50 minutes three times per week. The instructor's learning goals and lesson plans were nearly identical between the two sections, meaning that on most days the same example problems, voting questions, and demonstrations were presented to each section, and the topics of whole class discussions were similar. However, the environment of each section was notably different. One lecture section was taught in a classroom with a seating capacity of about 200, and which had been recently remodeled to make it more conducive to student-student interactions [21]. Instead of standard stadium seating consisting of a single row of fixed chairs on each tier, each tier of the remodeled classroom contained two rows of seats that could swivel, allowing students to more easily turn and face a direction other than the front of the classroom. The remodeled room also featured multiple display screens and other improvements and additions to the technology available to the instructor. The other section met in a classroom with a smaller seating capacity (around 125) and standard classroom features such as one projector screen and fixed, dense seating with one row of seats per tier [21].

Students chose to register for one section or the other—they were not assigned to attend a specific lecture section. While registering, students could see the room number in which the lecture would be held. Before fall term, the remodeled classroom had not been used, so it is unlikely that students were aware of the different classroom features when making registration choices for fall term. For winter and spring term registration, students were more familiar with the differences between the rooms. Students could move between the two classrooms from term to term.

The student population studied changed slightly from term to term. Table 1 shows end of term enrollment by term and by room. The large decrease in enrollment from Winter term to Spring term was most likely due to the fact that fewer departments required that their students complete the final term of introductory physics. The population studied was composed mainly of students majoring in science and engineering, and was predominantly male. The data for student population by major during Winter 2009 are shown in Figure 1. The distribution of majors was similar for Fall and Spring terms.

Table 1: Number of Students Enrolled at End of Term

Number of Students Enrolled at End of Term			
	Remodeled	**Traditional**	**Total**
Fall 2008	180	117	**297**
Winter 2009	201	116	**317**
Spring 2009	188	66	**254**

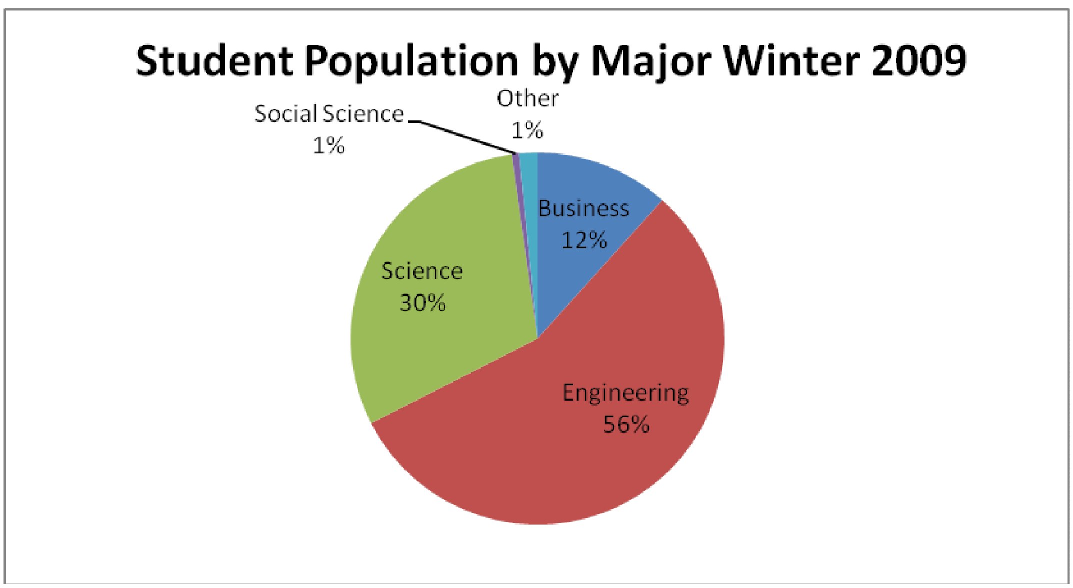

Figure 1: Student Population by Major Winter 2009

A typical 50-minute lecture section consisted of a combination of instructor presentation of material (similar to traditional lecture), demonstrations, examples, whole-class discussions, individual problem-solving episodes, and group problem-solving episodes. Often the problem solving sessions were presented in the form of voting questions, sometimes referred to as "clicker" or "audience response system" questions [8, 19]. Voting questions were facilitated through a Quizdom electronic response system, which allowed students to send in their answers or votes using their individual Quizdom remote controls. Responses could then be viewed by the instructor in real time and/or presented to the class. Students were graded according to whether or not they entered a vote, but were not graded for correctness of vote.

3.2—Data Collection

Various methods were used to observe different classroom practices, especially student interactions with other students or the lecturer. Data were collected for more than 80% of the days when lecture was taught. These data included video recordings taken at a wide angle so as to capture the majority of the students, as shown in Figure 1, and field notes taken on a detailed observation rubric (See Appendix A) by a student researcher observing lecture. The field notes allowed researchers to more easily identify episodes of small group discussion on the video recordings for analysis. Additional video recordings were also taken at other camera angles to be used in future studies.

Figure 2: Typical fields of view from wide camera angle.

3.3—Coding Video Episodes

After identifying small group discussion episodes, the instructor's introduction to the activity and instructor statements to the entire class during the activity were transcribed. Then the following time stamps were identified to aid in reviewing the videos:

1. **Introduction**—Time when instructor begins to talk about activity.
2. **Start**—End of Introduction. Instructor stops talking and expects students to begin discussing problem/activity.
3. **Uproar**—Time when students begin discussing with one another. (Often there is a gap between "start" and "uproar" as students process the problem or question at hand and prepare to discuss it.) In some episodes there was a clear uproar of student discussion, and in other episodes there was no distinguishable increase in student discussion after the start of the activity. In these cases, 15 seconds after the start time was designated as the "uproar" time.
4. **End**—The time marked "end" was when the teacher began a whole-class discussion or lecture, indicating the end of small group discussion time
5. **70%**—Found by calculating when 70% of the time between "uproar" and "end" had passed.

Videos taken from the wide angle shot are examined from the “uproar” to the “70%” mark on an activity. Each student fully visible in the wide angle video (roughly 70% of the students in each class) is classified as active, mix, or passive. An active student is defined as one who is always engaged in conversation (whether listening or talking). This engagement was defined by visibly turning their head or entire body to talk or listen to another student, gesturing, and moving their mouths as if in conversation. If a student seems disengaged from discussion for more than three seconds, that student is no longer classified as active. This could include them looking or turning away from their discussion partner(s), looking down at their desks, or studying something on the chalkboard or overhead display. Students who disengage for three seconds or more are classified as “mix.” The “mix” classification also includes students who only listen to other students and never talk. Students are counted as “passive” if they never engage in discussion when visible on camera during an activity. Students whose faces are never visible on camera are not counted under any classification, unless there is sufficient evidence from their positioning or posture that they fall under one of the three categories.

This method for classifying student participation in discussion has its limitations. Just because students are conversing does not mean that they are on-task. However, observations by the researcher in the classroom suggest that the majority of student interactions were on task, and audio recordings of a subset of groups support that finding. Another limitation of this method is that students who stop speaking or listening are not necessarily off-task. They may be diligently solving the problem, but are doing so alone. However, it is sensible that these students not be counted, since the aim of this method is to measure the number of students interacting with one another.

Five researchers coded the activities, with each activity being analyzed by at least two researchers independently. Inter-rater agreement at this stage was typically between 75%-90%. The researchers then discussed any major differences in their findings until inter-rater agreement of 90% or greater was reached.

Chapter 4—Results and Discussion of Video Coding

4.1—Overview of Student Participation in Group Discussion

After reviewing observer rubrics in conjunction with corresponding video recordings, 36 video episodes were selected for coding. The episodes chosen met the following criteria:

1. Contained an instance when the instructor allowed the students to discuss a question or problem in small groups.
2. Time period (beginning and end) of allowed discussion time was well-defined.
3. Question or problem was posed on the same day in both classrooms.

Of the 36 pairs (one in each room) of video episodes coded, ten were from Fall 2008, eleven from Winter 2009, and fifteen from Spring 2009. Tables describing all episodes appear in Appendices B and C.

The percentages of the total students on camera who were active, mix, or passive for each activity or episode are shown in the scatter plots below. Also shown is a graph of the percentage of students who were participants in group discussion (in other words, the sum of the active and mix participants for a given activity). Video episodes are plotted according to activity number, which corresponds to the order in which the activity occurred in the school year. Activity 1 having occurred near the beginning of the Fall term, and Activity 36 in the last part of Spring term. Episodes are not evenly spaced in time; some activities occurred on the same day, while other successive episodes occurred a week or more apart. Thus, these plots are not shown to obtain rigorous mathematical relationships between student participation and time elapsed from the beginning of the year. However, they do provide an overview of student participation in small group discussion throughout the academic year. It appears that student discussion tended to decrease as fall term, spring term, and the academic year overall progressed. Participation appeared to stay at about the same level throughout winter term, though.

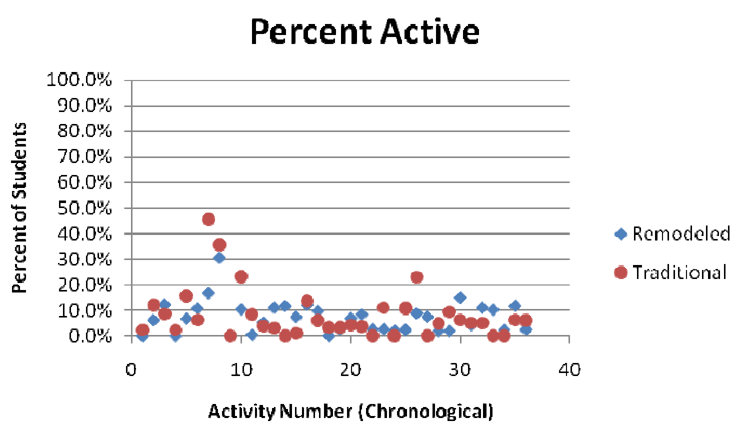

Figure 3: Percent Active vs. Activity Number

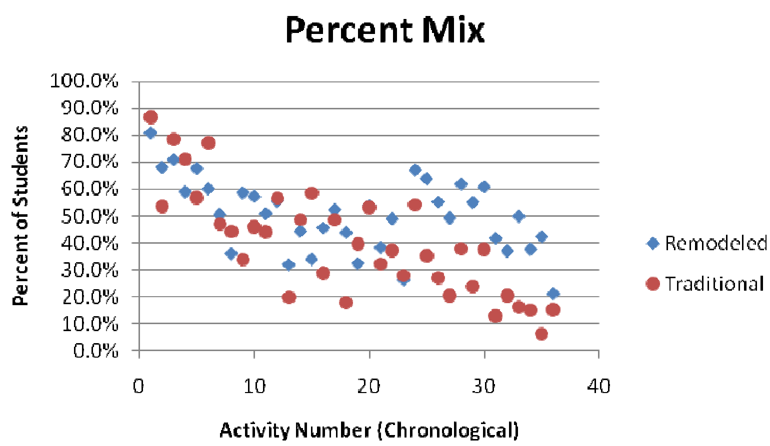

Figure 4: Percent Mix vs. Activity Number

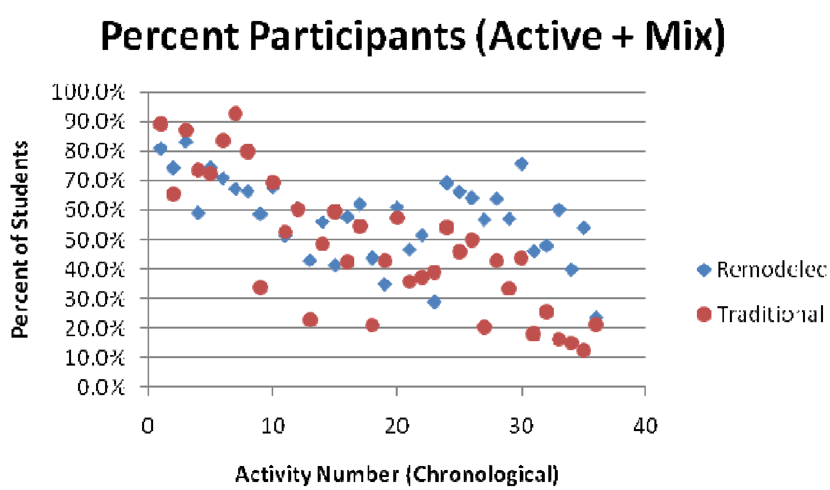

Figure 5: Percent Participants vs. Activity Number

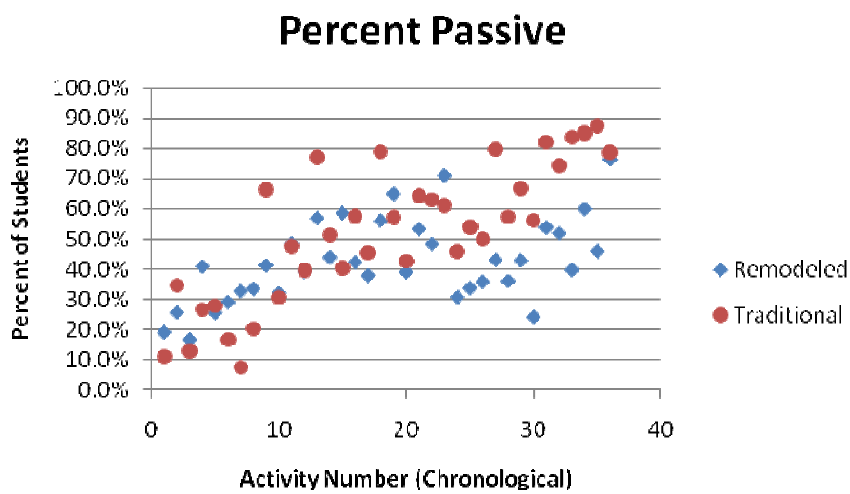

Figure 6: Percent Passive vs. Activity Number

The table of average percentage of participants (active and mix) shows that the average participation decreases from Fall to Winter terms in both rooms. It stays about the same from Winter to Spring in the remodeled classroom, but decreases again in the traditional classroom. This results in a large difference in average participation between the two classrooms during Spring 2009.

Table 2: Average Participation throughout the Academic Year

Average Participation (Percent Active plus Percent Mix)								
	Fall 2008		Winter 2009		Spring 2009		Academic Year	
	Avg.	St. Dev.	Avg.	St. Dev.	Avg.	St. Dev.	Avg.	St. Dev.
Remodeled	**70.4%**	8.2%	**50.8%**	9.3%	**53.8%**	14.6%	**57.5%**	13.9%
Traditional	**74.6%**	16.9%	**45.3%**	13.8%	**31.7%**	14.0%	**47.8%**	22.9%

This discrepancy is also seen in the plot of percent participants vs. activity number. During spring there is a noticeable gap between the two classrooms, with higher participation in the remodeled classroom than in the traditional classroom in almost every episode that term. A t-test comparing the two classrooms' percent participants over the course of the year gave a p-value of 0.0019, indicating that these data sets are statistically significantly different. A similar t-test that compared across the two classrooms for only the fall and winter terms had a p-value of 0.77, indicating that during these terms, the data sets are quite similar. The participation during spring term, then, is what makes the participation data between the two rooms distinct.

4.2—Interaction Time throughout the Year

The interaction time is defined as the time from the "start" to the "end" mark on a given video. The timing of an activity can certainly play a role in the effectiveness of an activity, and so is an important dimension of teacher facilitation to consider.

The teacher in this study kept most of the discussion times to between one and three minutes in length during winter and spring terms, as shown in Figure 7. During the beginning of fall term, interaction times were longer at about 5-6 minutes. The average interaction time for each term and each room is given in the table below. In both classrooms, the average interaction time per activity decreased each term.

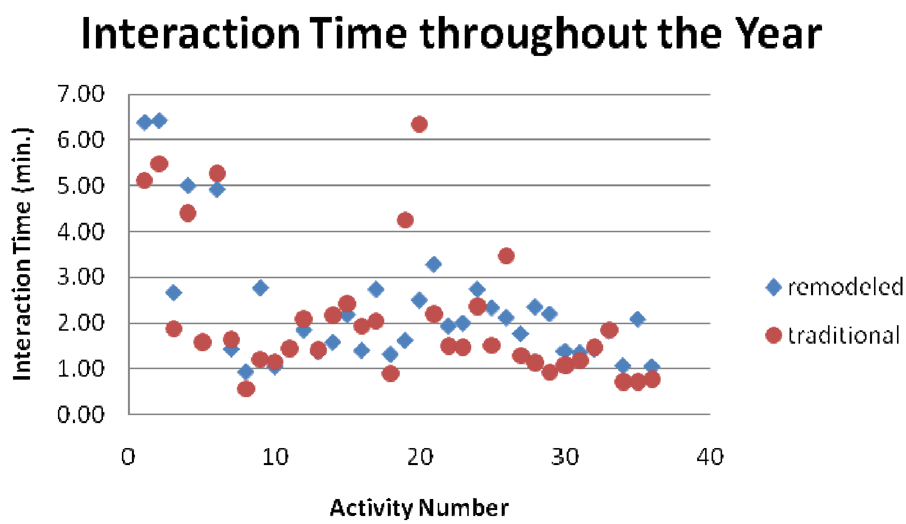

Figure 7: Interaction Time throughout the Academic Year

Table 3: Interaction Time throughout the Academic Year

	Interaction Time (min.)							
	Fall 2008		Winter 2009		Spring 2009		Academic Year	
	Avg.	St. Dev.	Avg.	St. Dev.	Avg.	St. Dev.	Avg.	St. Dev.
Remodeled	**3.3**	2.2	**1.9**	0.7	**1.8**	0.5	**2.3**	1.4
Traditional	**2.8**	2.0	**2.5**	1.5	**1.4**	0.7	**2.1**	1.5

To determine if there was a relationship between interaction time and participation in group discussion, percent participants was plotted against interaction time, as seen in Figure 8. No distinct functional relationship exists between interaction time and participation for these data; however, the correlation coefficient between the two variables is 0.44 for the remodeled classroom and 0.48 for the traditional classroom, indicating that there is a statistical correlation between these variables. As interaction time increases, percent of students participating in group discussion tends to increase.

The correlation between percent mix is even stronger, and is also positive, with a correlation coefficient of 0.61. A graph of mix participants versus interaction time appears below. The correlation coefficient between percent passive and interaction time is, -0.48, indicating that as interaction time increases, percent passive tends to decrease, which is as expected since percent participants would tend to increase. Little correlation exists between percent active and interaction time, with a correlation coefficient of -0.12. These results are discussed further in Section 4.4.

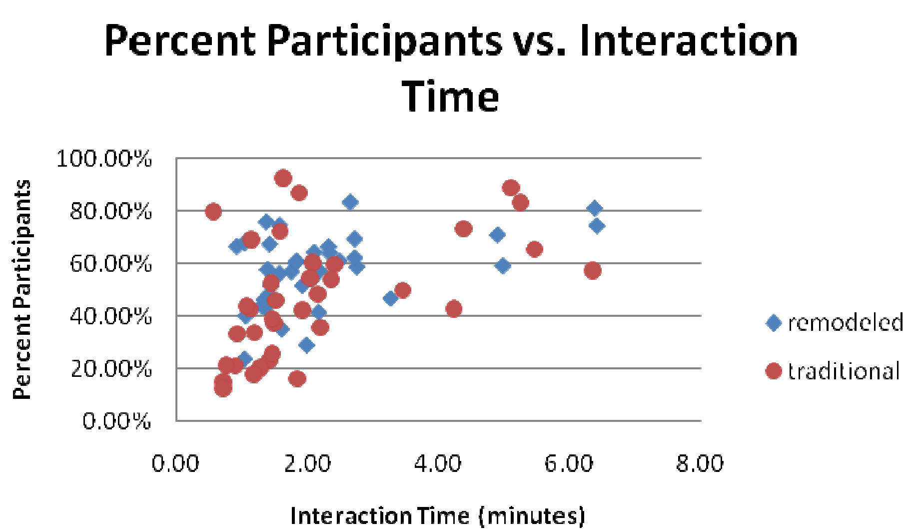

Figure 8: Percent Participants vs. Interaction Time

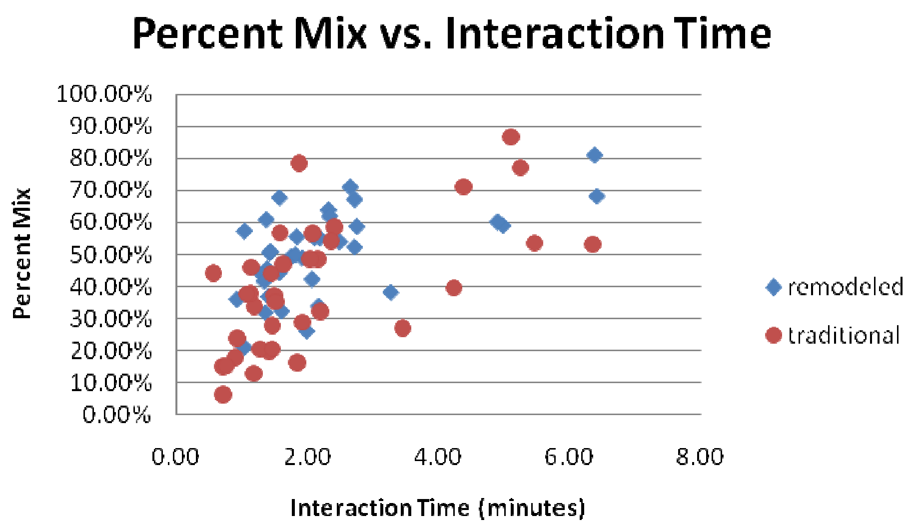

Figure 9: Percent Mix vs. Interaction Time

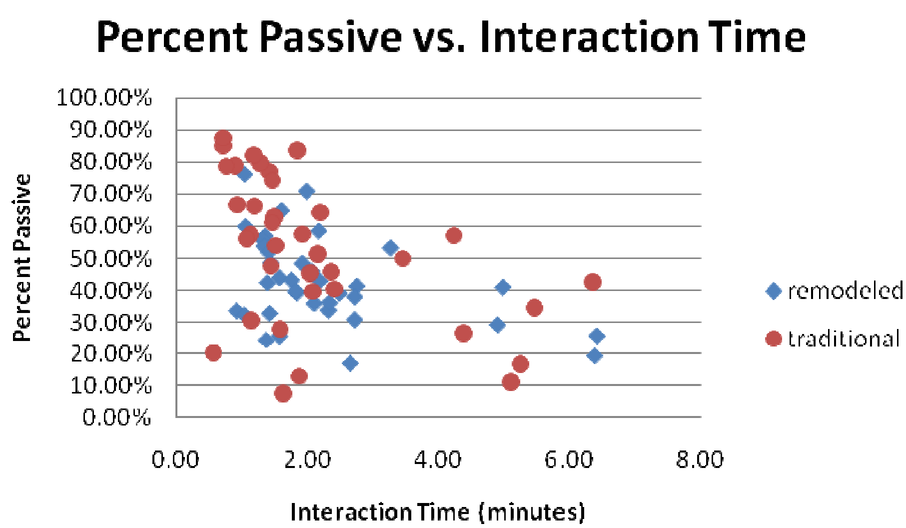

Figure 10: Percent Passive vs. Interaction Time

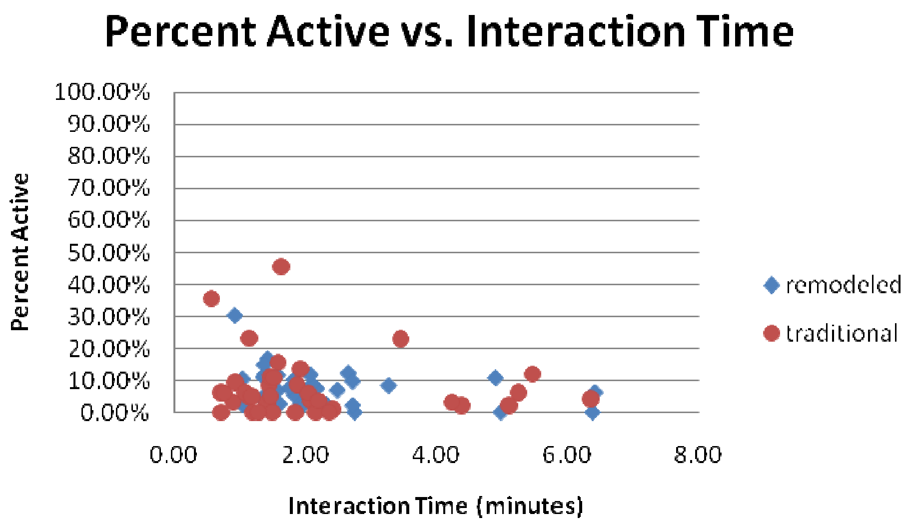

Figure 11: Percent Active vs. Interaction Time

4.3—Student Reasoning Heard throughout the Year

In the fall term, the instructor was often observed walking among students and listening to their reasoning during the small group discussion time. Whether or not these interactions correlate with participation in small group discussion is one of the questions guiding this research. (See Introduction). The number of episodes during which these teacher-student interactions occurred decreased from term to term, in part due to illness of the instructor for much of the winter and spring terms. (See Table 4). It should be noted that just as these Teacher-Student Discussions decreased from term to term, so did participation in small group discussion.

Graphs of percent participants versus activity number are shown below for each room. Activities for which the teacher interacted with students during the voting time appear as solid squares; activities for which this did not occur are shown as hollow squares. The average participation was higher for activities during which these interactions occurred than for activities that did not include teacher-student interactions. This was true for both classrooms.

Table 4: Teacher-Student Discussions during Activities

Percent of Activities during which Teacher-Student Discussions Occurred				
	Fall 2008	**Winter 2009**	**Spring 2009**	**Academic Year**
Remodeled	50%	27%	27%**	33%
Traditional	50%	18%	0%	19%
***Instructor spoke with students near front row—did not leave front of classroom.*				

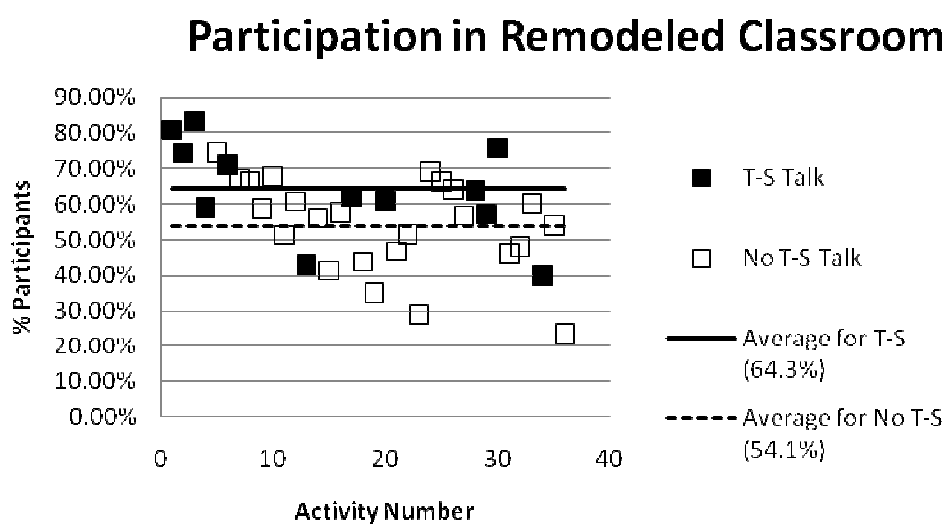

Figure 12: Teacher-Student Discussion and Participation for Remodeled Classroom

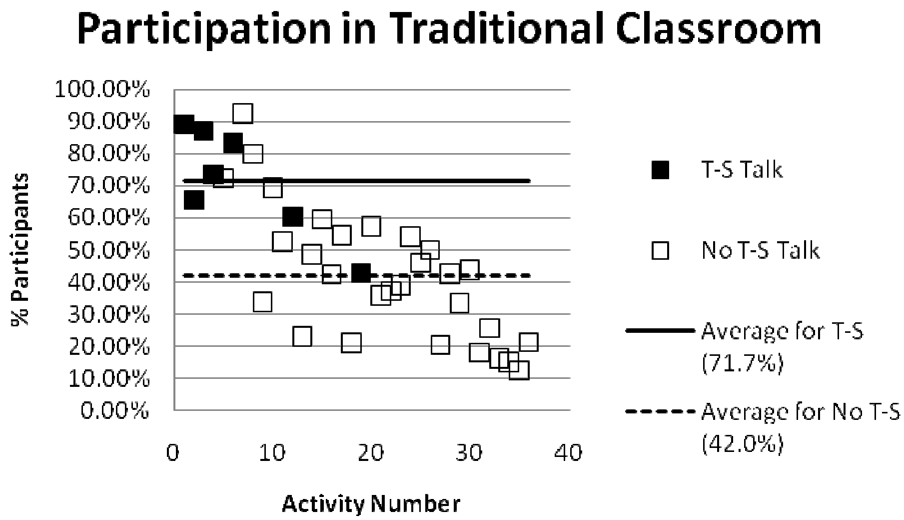

Figure 13: Teacher-Student Discussion and Participation for Traditional Classroom

Another question to address was the possible connection between students expecting to be asked to explain their reasoning and participation. One reason that students might expect to have to explain their reasoning is if the instructor consistently asks for students to explain their reasoning during the wrap up discussion to an activity. The instructor called on students to explain their reasoning during about half of the whole-class discussions following activities throughout the year in both classrooms. Listening to student reasoning, then, was a common occurrence after activities.

Table 5: Percent of Activities after which Students Explained Reasoning

Percent of Activities after which Students Explained Reasoning				
	Fall 2008	**Winter 2009**	**Spring 2009**	**Academic Year**
Remodeled	50%	55%	47%	50%
Traditional	70%	46%	73%	56%

4.4—Discussion of Trends in Student Participation

One of the most striking aspects of the data set is the decrease in participation observed throughout the academic year. The results of coding and transcribing videos suggest several possible explanations for this finding. It is conceivable that this decrease was related to a decrease in average interaction time, especially considering that the correlation coefficient between participation and interaction time was above 0.4. 28 of the 30, or 93%, of the activities with interaction times greater than or equal to two minutes saw at least 40% of the students participating in group discussion. Whereas only 64% of the activities lasting less than 2 minutes had at least 40% participation.

The instructor tended to stay near the front of the classroom more often as the year progressed and to have fewer conversations with students during the voting/discussion time. This decrease in teacher-student discussion may have decreased student motivation to discuss their ideas with their peers, since students were being held less accountable for articulating their reasoning. The perceived purposes of the activities later in the year, then, may have been to place a vote and to improve conceptual understanding and problem solving individually. Students may have been less likely to think that improving their scientific argumentation or reasoning skills was a goal of the activities. Thus, the decrease in the occurrences of teacher-student discussion during activities may be related to the decrease in activity level throughout the year.

On the other hand, it was shown in Section 4.3 that students were still being asked to articulate their reasoning during the wrap-up discussion for about 50% or more of the activities during all three terms in both rooms. In other words, activities where students explained their reasoning to the class afterward did not seem to decrease through the year. After reviewing the transcripts from the 24 activities discussed in Chapter 5, it was noted that in most cases, only one or two students articulated their ideas during these wrap-up discussions. Additionally, although it was sometimes difficult to tell from the camera angle, it seemed that the same handful of students would be observed sharing their ideas in front of the class from activity to activity. Thus, knowing that a few students might be articulating their reasoning at the end of an activity may not have been sufficient motivation for students to talk with their peers and prepare to articulate their reasoning, especially if students expected that they could rely on the same handful of their peers to be prepared with an answer.

Another of the most striking aspects of the participation data, was the wide gap in participation between the two classrooms during spring term. One of the most noticeable distinctions between the remodeled and traditional classrooms during the spring term was their population densities. In the remodeled classroom, well over half of the seats on camera were occupied by students for every activity examined. The traditional classroom felt empty by comparison during spring term. For most video episodes analyzed during this term, less than half of the seats on camera were occupied by students. There was often an echo in the room. Some students were more than one seat away from their closest neighbor, although they easily could have chosen to sit in a more compact seating arrangement. This difference in the physical distribution of students throughout the room may be related to the difference in participation between the two classrooms during the spring term.

Chapter 5—Findings from Transcript Analysis: Participation and the Occurrence of Facilitation Techniques

From the 36 activities (72 episodes) examined, 12 were selected for more detailed analysis based upon percent participation. Activities were chosen for further examination if they had "Very High" (more than one standard deviation above the term average for the room) or "Very Low" (more than one standard deviation below the term average for the room) participation in both rooms relative to the average term activity in each room. Activities with large differences in participation between the two classrooms were also selected. These activities are summarized in Appendix C. Episodes were classified as having "High" participation if they were above but not more than one standard deviation above the term average participation for the room, and were classified as "Low" participation if they were below but not more than one standard deviation below the term room average.

While reviewing transcripts, several discussion prompts were identified. In this study, a "discussion prompt" is defined as an instructor statement that requests, suggests, or proposes that students communicate with one another. Discussion prompts were given for all ten (100%) of the Very High activities and for both (100%) of the two High activities. One of these prompts was phrased as a suggestion rather than a request or command. On the other hand, only one (25%) of the four Low activities included a discussion prompt. Discussion prompts were heard during two of the eight (25%) Very Low activities. For one of the two Very Low activities, the prompt was phrased as a suggestion ("…so I don't mind if you talk or not talk") rather than as a request or command. The instructor reports that this choice of phrasing was often made with a different goal in mind than the goal of encouraging a lot of discussion. She probably felt that some activities were better suited to group discussion than others. Nevertheless, these results indicate that explicit requests to discuss with peers may result in greater participation in small group discussion.

The phrasing of the discussion prompt may also affect the level of participation. The two activities which included a prompt to "convince" a neighbor of their reasoning occurred on the same day and were both of a Very High participation level. During two other Very High activities students were asked to "work it out" with their neighbor, and then later to "turn to someone new" and explain it to them. Another key word used during yet another Very High activity was the prompt to "help" their neighbors. Only one of these phrases occurred for the Low or Very Low activities, and that was the term "convince." Near the 70% coding time of a Very Low activity the instructor told students, "feel free to talk to your neighbor and change your vote if they convince you of a better answer." This statement could easily be interpreted to mean "talk with your neighbor if you feel you were wrong," which is distinct from requesting that students convince their peers that they are right.

Of the 24 episodes analyzed in detail, six included the teacher implying or stating that student-student interactions were helpful or could enhance performance. Four of the six (75%) were Very High activities, and two were Low activities. One of these Low activities had a better participation rating than its Very Low counterpart in the other room, where such a teacher statement was not made. It is difficult to say anything conclusive about such a small sample size, but the fact that most of these statements occurred for activities with high participation raises the question as to whether such declarations improve participation.

In a few cases, the instructor assigned a rating to the voting question. In three episodes, she referred to the voting question as "easy," and in all three of these episodes participation was Very Low. In three other episodes, she stated or implied that the problem was difficult, and in all of these episodes participation was Very High. In the introduction to one of these activities she said that the problem covered a "very important concept" and that it had a "lot of information in it, and [was] worth thinking about carefully," which implied that the problem was not particularly easy. In the other two activities she specifically refers to the voting questions as "hard" and "harder." It should also be noted that the instructor likely had different goals in mind in terms of participation as she made these different statements about problem difficulty, according to comments made by the instructor after reviewing the transcripts.

The data suggest or raise the question as to whether these facilitation techniques influence student participation in small group discussion. However, it is difficult to eliminate other variables and examine the impact of each technique alone. It should be noted that compounding factors such as multiple facilitation techniques occurring at once, nature of the activity or problem statement, and student morale make it difficult to conclusively determine how specific teacher facilitation techniques influence student participation.

Chapter 6—Activities with Significant Differences in Participation between Classrooms

To eliminate variables related to the nature of the problem, the participation results for identical problems/activities can be compared across the two classrooms. This can be particularly insightful when an activity has high participation in one classroom and low participation in the other. Of the twelve activities that underwent the second round of analysis, four meet this description. These are discussed in detail in the following sections.

6.1—Fall-07: Comparison of Angular Speeds

One of the highest participation levels (Very High) of the fall term occurred in the traditional classroom during this activity, while the participation was slightly below average (Low) in the remodeled classroom. The voting question, shown in Figure 14 below, served as part of an introduction to rotational motion, and was presented in the manner of a typical 2-part PI problem with time for individual voting, followed by time for group discussion and voting. This question is conceptual in nature, although an algorithm could also be applied in order to solve it.

A lady bug sits at the outer edge of a merry-go-round and a gentleman bug sits halfway between her and the axis of rotation. The merry-go-round makes a complete revolution once each second. The gentleman bug's angular speed is:

1Half the lady bug's.

2The same as the lady bug's.

3Twice the lady bug's.

4Impossible to determine.

Figure 14: Rotational Motion Voting Question

6.1.1—Before Activity Fall-07

In both classrooms, there was a short lecture introducing rotational kinematics directly before the voting question was posed. In the traditional classroom, this lecture included the teacher posing a question to the students which asked them to compare centripetal acceleration to angular acceleration. She stated that angular acceleration is due to speeding up or slowing down. She asked, "What was this [centripetal acceleration] due to? What caused this acceleration? Was it speeding up or slowing down?" After which students shouted out brief answers and she continued lecturing. This question-response episode did not occur in the remodeled class.

Also during this time, the instructor stated that they would only be dealing with constant angular velocity this term, although one of the Mastering Physics problems she had selected for them to do was generating initial conditions where it was not constant. She brought up this inconsistency and apologized in both classrooms. In the remodeled classroom she brought up another inconsistency before introducing the voting question—the fact that the notation she had been using that day for the "initial" subscript did not match the notation they had been using on previous days. She explained that the "0" and "i" subscripts both indicated an initial condition. In the traditional classroom, this inconsistency was not mentioned, which may have made the instructor appear more organized or aware than in the remodeled class.

6.1.2—Introduction to Activity Fall-07

Another difference in the facilitation of the activity was the mention of a time constraint as the teacher introduced the activity in the remodeled classroom ("I have about 10 more minutes of stuff to do in 3—"). The start of the discussion portion of this activity occurred only about 4 minutes and 15 seconds before the end of class, which ended up constraining the interaction time of the activity to about one and a half minutes. Turning the students' attention to the clock with less than 5 minutes left in the class period could easily have been distracting, as the low participation values indicate.

The traditional classroom was given about the same amount of discussion time (approximately one and a half minutes), and the teacher made no mention of a time constraint at the beginning of the activity, probably due to the fact that the discussion portion of the activity started about 9 minutes 15 seconds before the end of class, meaning that the teacher likely felt less hurried in this classroom.

The problem was presented in a two-part PI-type sequence, with time allotted for individual voting, and then time for discussion and voting. The phrasing of the introduction to the individual voting portion varied distinctly between the two classes. In the remodeled classroom, the instructor said, " I have about 10 more minutes of stuff to do in 3, so I'm going to give you the voting question and save the demo for Friday 'cause the demo is review. So go ahead and vote on this one by yourself." To a student, it may appear that the instructor has a list of things to accomplish and this activity is simply a task they need to work through so it can be checked off this list. In the traditional classroom, the teacher provides insight into her motivation for including this activity in her lesson plan: "Alright, now we're going to do voting questions. Give you a chance to think about how to apply these things." She clearly states that she is providing an opportunity for students to come to a better understanding of the concepts under discussion. This statement could also imply that students are responsible their learning. This discrepancy between the stated motives for incorporating the activity could play a role in the participation differences between the two classrooms.

In both classrooms, students were asked to speak with their neighbors during the second half of a two-part PI-type sequence, but the phrasing of this request varied across the two classrooms. During the introduction to the group discussion piece of the activity in the remodeled classroom the teacher told the class, “I see from the results so far that it would help you to talk to your neighbor, so go ahead and do that.” She directly requested that students talk with one another (“go ahead and do that”), and she also implied that student-student interactions could improve their results (“…it would help you to talk to your neighbor”). The instructor also provided guidance for how to go about solving the problem during this time. She pointed them to a problem solving tool by stating that, “drawing a picture would be helpful,” and provided some scaffolding by asking students to “ [consider] where those bugs will be some time later and how the angles compare.”

The introduction to the discussion portion of the PI sequence was slightly different in the traditional classroom, or the classroom with the higher participation: “Ok. At this point now that I’ve seen the results, I want you to convince your neighbor of the reasoning behind your answer.” Instead of requesting that students “talk” she asks that they “convince” each other of their reasoning. Her request to this classroom is phrased as a personal desire (“I want you to”) rather than a direct command (“do that”) as in the other classroom. Unlike what was done in the remodeled classroom, she did not mention or suggest any problem solving strategies. This is interesting, because the instructor found that giving strategies to the students often seemed helpful. In this case, however, it did not appear to outweigh the other factors that may have discouraged participation in the remodeled classroom.

6.1.3--During Activity Fall-07

In the traditional classroom, the teacher walked up and down the aisle, but did not interact with students other than to address a technical issue with the voting system and to announce that the students had 20 more seconds to vote. The instructor remained at the podium in the remodeled classroom during voting time, and did not interact with students during the episode other than to make a brief announcement that the students had 20 more seconds to vote. These timing announcements both occurred just before the coding time ended.

Table 6: Overview of Activity Fall-07

	Remodeled			**Traditional**		
Participation	Active: 16.7%	Mix: 50.6%	Passive:32.7%	Active: 45.7%	Mix: 46.9%	Passive: 7.4%
	Participation (A+M): 67.3% (3.0% lower than term average)			Participation (A+M): 92.6% (18.0% higher than term average)		
Before	Lecture on rotational kinematics			Lecture on rotational kinematics		
	---			Question/Response episode about acceleration		
	Mentions Mastering Physics inconsistency			Mentions Mastering Physics inconsistency		
	Mentions instructor notation inconsistency			---		
Introduction	Time constraint mentioned			---		
	Voting Question = Item on Checklist			Voting Question = Opportunity for Student Learning		
	Discussion Prompt: Command to “help”			Discussion Prompt: Personal Request to “convince”		
	Implies student discussion improves performance			---		
	Problem-Solving Hints: Mentions tool, Scaffolding			---		
During	Instructor remains at front of classroom.			Instructor walks around classroom.		
	---			Addresses technical issue with voting system.		
	Brief announcement about time left to vote.			Brief announcement about time left to vote.		

6.2—Winter-05: Diffraction Grating

The remodeled classroom had Very Low participation values for this activity, while the participation in the traditional classroom was Very High. The voting question, shown below, related to one of the main topics of discussion for the day—diffraction. The question requires that students apply an algorithm, but they must apply it more than once and combine their results, meaning that there is a conceptual aspect to this question as well.

A diffraction grating is illuminated with yellow light at normal incidence. The pattern seen on a screen behind the grating consists of three yellow spots, one at zero degrees (straight through) and one each at ±45°.You now add red light of equal intensity, coming in the same direction as the yellow light. The new pattern consists of

1. red spots at 0° and ±45°.
2. yellow spots at 0° and ±45°.
3. orange spots at 0° and ±45°.
4. an orange spot at 0°, yellow spots at ±45°, and red spots slightly farther out.
5. an orange spot at 0°, yellow spots at ±45°, and red spots slightly closer in.

Figure 15: Diffraction Grating Voting Question

6.2.1—Before Activity Winter-05

In both classrooms the teacher derived an equation describing double slit interference. She talked about the assumptions used and shows a simulation of double slit interference to help explain the derivation. In the traditional classroom, she asks the students about the consequences of the assumption that the frequency of the light passing through each slit is the same. Two brief student responses are heard by the entire class.

6.2.2—Introduction to Activity Winter-05

The instructor introduced the voting question with very brief statements in both classrooms. In the remodeled classroom she simply stated, "I'm going to switch to a voting question. [pause] This one." She makes no mention of the students, of group discussion, or of the concepts discussed in the problem.

In the traditional classroom she said, "Have a voting question for you that you're gonna nail, I know." Although this introduction is also abrupt, the teacher does mention the students and expresses confidence in them. She says she has a voting question "for [them]" perhaps implying that she's providing this activity for their benefit, or implying that this is a chance for them to take an active role in their learning of physics. By stating that she knows they are "gonna nail" the problem, the teacher is communicating her expectation that students will correctly solve the problem. Perhaps this expression bolsters the confidence of the students, or perhaps it sets a goal or provides a motivation for the students to perform well. In any case, this statement of expectation is one of the only differences between the teacher facilitation of the activity in the two classrooms, and as such, could account for some of the discrepancy in participation levels.

6.2.3—During Activity Winter-05

During the time provided for voting, a student in the remodeled classroom asks Dedra if she would adjust the document camera, and Dedra responds by making an adjustment. Other than this brief interaction over a technical issue, there is no interaction between the teacher and a student or small group of students in either classroom until the wrap-up discussion. The teacher remains at the front of the classroom—either working at her desk or working with the equipment for an upcoming demonstration for the duration of the activity.

About 25 to 30 seconds before the 70% time in each classroom, the teacher makes an announcement. In the remodeled classroom she states, “Give you 15 more seconds. And talk to your neighbors. So far so good.” In the traditional classroom, her statement is very similar: “Give you 15 more seconds. Talk to your neighbors. You’re on the right track.” In both classrooms she gives students a time limit for completing the activity and voting, she prompts them to talk with one another, and she provides a positive evaluation of the voting results at that point in time.

Table 7: Overview of Activity Winter-05

	Remodeled			Traditional		
Participation	Active:7.4%	Mix: 34.0%	Passive: 58.6%	Active: 1.0%	Mix: 58.5%	Passive: 40.4%
	Participation (A+M): 41.4% (9.4% lower than term average)			Participation (A+M): 59.6% (14.3% higher than term average)		
Before	Lecture on diffraction			Lecture on diffraction		
Introduction	"I'm going to switch to a voting question. [pause] This one."			"Have a voting question for you that you're gonna nail, I know."		
	---			Voting Question = Opportunity for Student Learning		
	---			Instructor Expectation: Correct responses		
During	Instructor remains at front of classroom			Instructor remains at front of classroom		
	Student requests adjustment of doc cam			---		
	Discussion Prompt: Command			Discussion Prompt: Command		
	Time Limit			Time Limit		
	Positive evaluation of voting results			Positive evaluation of voting results		

6.3—Spring-02: Electric Potential Energies of Charge Configurations

Of the 15 activities analyzed for the spring term in the remodeled classroom, this activity had the second lowest participation values, with the percentage of total participants being a mere 29%. In the traditional classroom the participation was 39%, which was above the classroom average for the term of 31%. The voting question, shown below, addresses electric potential energy, one of the main topics being addressed in lecture. This question requires both conceptual reasoning and the application of an algorithm (the equation for electric potential energy).

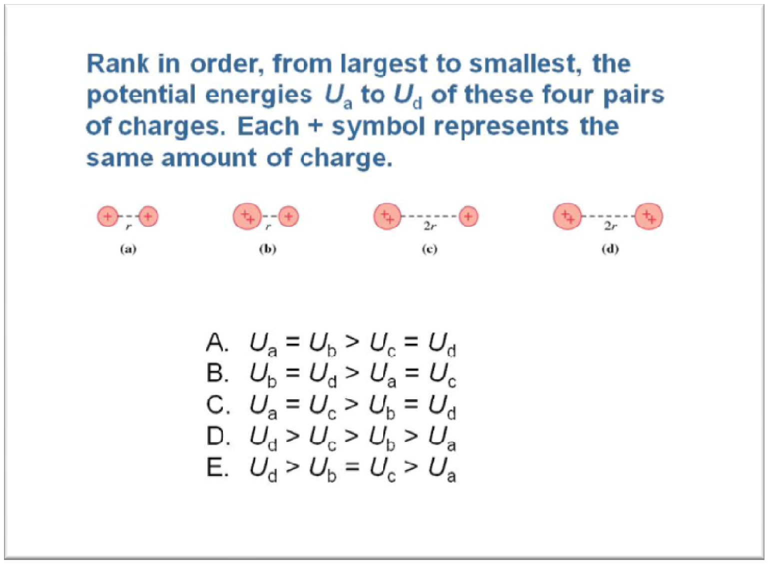

Figure 16: Electric Potential Energy Voting Question

6.3.1—Before Activity Spring-02

In both classrooms, the instructor gives a voting question before introducing the voting question under examination. This first voting question related to the electrostatic potential energies of different charge distributions. In the traditional classroom, a student asked a question in the middle of the voting time, and the instructor responded in front of the entire class. She then asked the students to talk with their neighbors. During the wrap-up discussion of this voting question the teacher asked, “Why is it ‘A’?” listened to students shout out responses, and then continued lecturing.

There were no student comments or questions heard by the entire class during the voting portion of the activity in the remodeled classroom. During the last portion of the voting period, the teacher asked students to talk to their neighbors and then stated, “See if you can increase the amount of correct answers.” During the wrap-up, the teacher asked students what the answer was, several students replied, “A,” and then the teacher stated that the sign of the charges mattered. She then introduced the voting question.

6.3.2--Introduction to Activity Spring-02

The teacher’s introduction to this activity was brief in both classrooms. In the remodeled classroom, she stated, “Let’s give you an easier one. Well, I don’t know, actually.” The teacher said that she was giving a voting question to the students, which may have implied that this was being done for their benefit. Although she originally evaluated the problem as “easy” she then retracted her statement. It should be noted that there was no mention of or request for student-student discussion, nor was there any discussion of the physics concepts relating to the problem.

In the traditional classroom, the teacher introduced the activity by simply stating, “How about this one.” The only apparent function of this comment was to indicate to the students that they were moving on to discuss a different problem. Again, no mention of talking to peers, or discussion of relevant physics topics occured in the introduction to the problem.

6.3.3--During Activity Spring-02

After introducing the problem in the remodeled classroom, a technology malfunction occurred, and for about 35 seconds of the total two-minute interaction time, the instructor discussed the issue with a student and worked to eventually remedy the situation.

In the traditional classroom these technical issues did not arise. The only interaction between the teacher and class during the voting time was a statement made to the entire class about 20 seconds before the end of the coded portion of the episode. The instructor announced, “Encourage you to keep talking with your neighbors. Work this one out.” Unlike in the remodeled classroom, the instructor does prompt the students to talk with one another.

Table 8: Overview of Activity Spring-02

	Remodeled			**Traditional**		
Participation	Active: 2.6%	Mix: 26.3%	Passive: 71.1%	Active:11.1%	Mix: 27.8%	Passive:61.1%
	Participation (A+M): 29.0% (24.8% lower than term average)			Participation (A+M): 38.9% (7.2% higher than term average)		
Before	Voting Question			Voting Question		
	---			Instructor answers student question during voting		
	Discussion prompt			Discussion prompt		
	“What is the answer?”			“Why is it ‘A’?”		
Introduction	Voting Question = Opportunity for Student Learning			“How about this one.”		
	Evaluation of Problem: “Easy…well, I don’t know.”			---		
During	Instructor remains at front of classroom			Instructor remains at front of classroom		
	Technology Malfunction			---		
	---			Discussion Prompt: “Encourage[s]” students to talk, “work this one out”		

6.4—Spring-12: Magnetic Induction

The participation level in the remodeled classroom during this episode was above the term room average. Students seemed fairly engaged with their hands in the air using the right hand rule. Participation in traditional classroom for this same activity was Very Low. Researchers coding these videos noted a distinct difference in the animation of students between the two classrooms. The voting question, shown in the figure below, was conceptual in nature. It addressed the concept of magnetic induction, one of the main topics discussed that day.

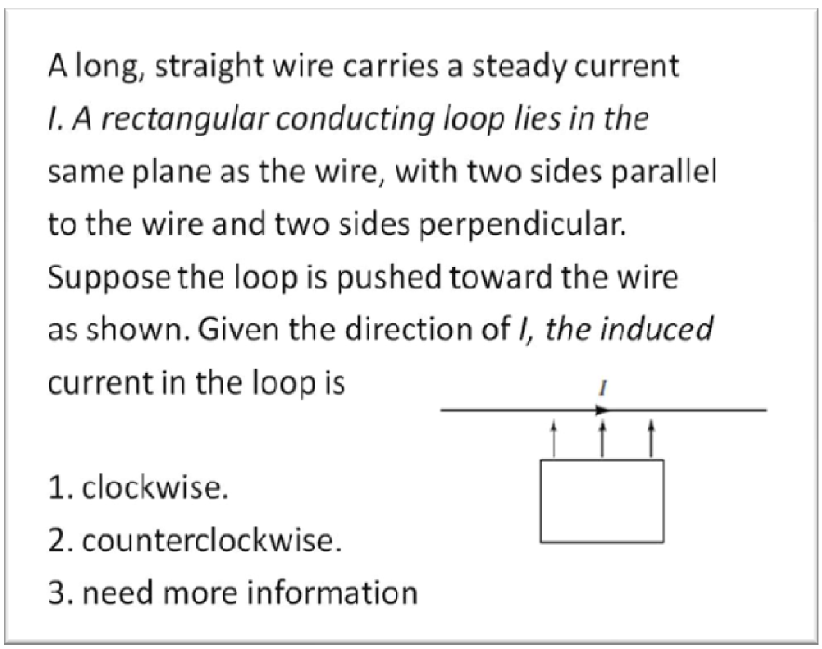

Figure 17: Magnetic Induction Voting Question

6.4.1—Before Activity Spring-12

The instructor leads into the voting question in both classrooms by working through an example problem on magnetic induction. In the remodeled classroom she follows this by showing two videos on induction sent to her by students, and then proceeding to the voting question. She thanks the students for sending the videos in, and states that she "definitely think[s] induction is the coolest topic of the year." By using student submissions in her lecture, she is promoting the notion that students are valuable contributors to the classroom community. In the traditional classroom she does not show the videos and moves straight to the problem.

6.4.2—Introduction to Activity Spring-12

In both classrooms, the introduction to the problem was quite brief. In the remodeled classroom the teacher simply said, "Your turn to review," as she displayed the problem. In the traditional classroom she started by stating something very similar: "It is now your turn to review." Using the phrase "your turn" may signify that the students are now responsible to take an active role in learning or reviewing the ideas discussed. The teacher also asked the class in the traditional room, "Any questions on this problem (the previous example problem) before I switch it over?" thus drawing their attention away from the problem that she had just introduced.

6.4.3—During Activity Spring-12

About 30 seconds before the end of the coding time, the instructor announced in the remodeled classroom, “Well, so far all of you have figured out that you can solve it. So three’s not the answer, but you’re pretty split between A and B. Help your neighbors out. Use the right hand rule.” The teacher provided a hint by narrowing down the options that the class has to choose from, and by reminding them of a tool (the right hand rule) that they could use to solve the problem. She prompted them to talk with or “help” one another. Again, implying that as students they can serve a valuable role in the teaching that takes place in the classroom.

An announcement made in the traditional classroom about 30 seconds before the end of the coding time was the following: “Here’s a case, by the way, that we almost never do computationally because the magnetic field is not constant through the loop, it’s stronger when you’re closer to the wire. So we have a stronger B-field here and a weaker B-field here [pointing to diagram]. It’s not too bad to do, but a little bit much for first year.” The instructor prompted the students to consider the more difficult problem of finding the numerical value for the current. It may have served as a nice extension to the problem statement, but did not provide any guidance for answering the question that was actually posed. Upon reviewing the video, the instructor commented that her statement was made in reply to a student’s question, and perhaps her comments were a bit confusing or distracting for the other students. No prompt to engage in discussion was heard before the end of the coding time for this video.

Table 9: Overview of Activity Spring-12

	Remodeled			Traditional		
Participation	Active:10.3%	Mix: 50.0%	Passive: 39.8%	Active: 0%	Mix: 16.3%	Passive: 83.7%
	Participation (A+M): 60.3% (6.5% higher than term room average)			Participation (A+M): 16.3% (15.4% lower than term average)		
Before	Example problem on magnetic induction			Example problem on magnetic induction		
	Shows 2 videos submitted by students			---		
Introduction	Voting Question = Opportunity for Student Learning			Voting Question = Opportunity for Student Learning		
	---			Possible Distraction: Asks about Previous Problem		
During	Instructor remains at front of classroom			Instructor remains at front of classroom		
	Problem-Solving Hints: Mentions tool, Narrows down answer choices			Possible Distraction: Responds to student question concerning a more advanced related problem		
	Discussion Prompt: Command to “help”			---		

6.5—Summary of Findings from the Four Activities

After a more detailed analysis of four activities (8 video episodes) for which participation was high in one classroom and low in the other classroom, more facilitation techniques that appeared to affect participation were identified. As with the other facilitation techniques and patterns observed in this study, further investigation of these techniques is needed to provide greater insight about their effects on student participation. Future work could include the investigation of these techniques, which are listed below.

Instructor Facilitation Techniques that May Correspond with Low Participation:

- Calling students attention to the clock by mentioning a time constraint, particularly near the end of a class period.
- Listing the small group activity as an item on a checklist, without providing further justification for incorporating the activity.
- Interrupting the small group discussion time with announcements unrelated to the problem or activity.

Instructor Facilitation Techniques that May Correspond with High Participation:

- Listening to students' reasoning, answering student questions, or recognizing students as contributors to the classroom community in a whole-class discussion before a small group activity.
- Referring to the small group activity as a chance for students to take an active role in their learning.
- Asking students to "convince" a peer of their reasoning, rather than simply asking them to discuss or talk.
- Voicing the expectation that students will perform well on the activity or problem.

Chapter 7—Conclusion

Videos taken in an introductory calculus-based physics sequence were analyzed to determine student participation in small group discussion and teacher facilitation techniques that foster or hinder these interactions. This physics sequence was taught in two different lecture sections, one of which met in a classroom remodeled for the purposes of fostering student-student interactions, and the other met in a more traditional classroom. A total of 72 video episodes (corresponding to 36 problems or activities posed in two different lecture sections) were coded independently by two researchers to determine the number of students who were active, mixed participants, or passive. 24 of these 72 video episodes (corresponding to 12 problems or activities posed in the two different lecture sections) were transcribed to look for patterns of teacher facilitation that might have affected the number of students participating in small group discussion. The research questions presented at the beginning of this thesis and their corresponding responses obtained through data analysis are presented in summary below.

1. ***How does student participation in small group discussion change over the course of an academic term and over the course of an academic year?*** Student participation tended to decrease in both classrooms as the academic year progressed. Participation tended to decrease through fall and spring term, but stayed fairly consistent throughout winter term.

2. ***Are there changes in instructor facilitation of activities that may correlate with observed changes in student participation?*** The data suggest at least two factors that may have contributed to the decreasing trend: a decrease in time allotted for student interactions from term to

term and a decrease in the amount of student-teacher interactions during small group discussion time.

3. ***In what ways does the timing of an activity correlate with student participation in discussion during the activity?*** As mentioned in the response to Question 1, the interaction time given for activities tended to decrease throughout the year, as did student participation. Further evidence of the relation between interaction time and percent of students participating in discussion, is the correlation coefficient between these data sets (0.44 for the remodeled classroom, 0.48 for the traditional classroom)

4. ***How do instructor statements made before an activity, during the introduction to an activity, and during the small group discussion portion of an activity correlate with student participation in discussion?*** Certain instructor statements tended to occur more often for activities with high participation, suggesting that they may foster student discussion. These techniques included: prompting the students to talk with their neighbors (particularly requesting, not just suggesting), implying or explicitly stating that student discussion benefits learning, and rating the problem as "important" or "difficult." In the study of the 24 video episodes and transcripts, rating the problem as "easy" always (in three instances) coincided with low participation.

5. ***Do trends in the amount of student reasoning heard by the teacher and entire class correlate with trends in student participation in discussion?*** As mentioned in the response to Question 1, there was a decline throughout the year in the amount of activities for which student-teacher interactions occurred during small group discussion time, which may relate to the decrease in participation. It was also noted that participation tended to be high for activities for which the instructor listened to students' reasoning, answered student questions, or recognized students as contributors to the classroom community in a whole-class discussion before a small group activity.

Other patterns were observed as these research questions were being answered. These findings, as well as those discussed in Questions 1-4, are summarized in Table 7.1.

There are many related avenues of research still to be explored. Through examination of video recordings focused on smaller groups of students, information about the nature of student interactions can be obtained. By matching these observations with the data obtained in this study, links can be identified between teacher facilitation of student discussion and the types of student interactions that occur. Further analysis of these videos can be used to study the effects of classroom features and teacher facilitation on the number and size of student groups being formed during large lecture. Finally, by applying the same research questions examined in this study to data from other years or from classes taught by different instructors, a more generally applicable set of discussion facilitation strategies can be established. Hopefully, building off of this research will allow more techniques to be identified that will allow instructors to enhance the number and quality of student interactions in the science classroom.

Table 10: Overview of Instructor Techniques Corresponding with High or Low Participation

Factors that correlate with and/or occur for activities with:	
High Participation	**Low Participation**
Interaction Time > 2 min.	Interaction Time < 2 min.
Teacher-Student discussion during voting	Drawing attention away from problem during voting
Instructor requests that students talk to peers	---
Instructor implies or states that student/student interactions benefit learning	---
Instructor rates problem “hard” or “important”	Instructor rates problem “easy”
---	Mention of time constraint, particularly near end of class period.
Referring to activity as chance for students to take an active role	Referring to activity as item on a checklist
Voicing the expectation that students will perform well on an activity	---
Higher population density	Lower population density, room feels more empty

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APPENDICES

Appendix A—Observation Rubric for Fall 2008

	Interaction
Telling/T monolog	Example/demo/simulation
	Review
	Model skill
	Presenting information
	Pose a question (rhetorical)
TS dialog	Picking a S
	Sampling questions
	Pose a question (clicker)
	Representation question
	What do you think?
	Does it make sense?
	Guiding questions
	Consensus question
	Volunteer information
	Using student input
	Direct answer
	T humor
	Express emotions
ST dialog	S answering
	S confusion/silence
	Asking a question
	S reasoning
	Metacognition
	Making sense of problem
	Challenge others
	S humor
	Express emotions
	Technical corrections
Auth.	Authority b/w S&T
	Cede authority to text
	Cede authority to exp results
SS interaction	Understand task
	Simple agree
	Share information
	Solicit information
	Support solution
	Challenge others
	Metacognition
	Attention focus
	Express feeling towards task
Other	Do teacher's own work
	Administrative stuff

Appendix B—Overview Table of Activities in Remodeled Classroom

Activity Number	Activity Name	Date	Interaction Time (minutes)	Number of Students on Camera	Percent Active	Percent Mix	Percent Passive	Percent Participants (Active + Mix)
1	Fall-01	10/8/2008	6.4	118	0.0%	81.0%	19.0%	81.0%
2	Fall-02	10/10/2008	6.4	107	6.2%	68.2%	25.6%	74.4%
3	Fall-03	10/13/2008	2.7	123	12.2%	71.0%	16.7%	83.3%
4	Fall-04	10/15/2008	5.0	97	0.0%	59.1%	40.9%	59.1%
5	Fall-05	10/15/2008	1.6	89	6.8%	67.7%	25.5%	74.5%
6	Fall-06	10/17/2008	4.9	93	10.7%	60.2%	29.1%	70.9%
7	Fall-07	10/20/2008	1.4	78	16.7%	50.6%	32.7%	67.3%
8	Fall-08	10/24/2008	0.9	96	30.4%	36.1%	33.5%	66.5%
9	Fall-09	10/27/2008	2.8	95	0.0%	58.8%	41.2%	58.8%
10	Fall-10	10/27/2008	1.1	106	10.4%	57.4%	32.2%	67.8%
11	Winter-01	2/4/2009	1.5	108	0.5%	50.9%	48.6%	51.4%
12	Winter-02	2/6/2009	1.9	86	5.3%	55.6%	39.2%	60.8%
13	Winter-03	2/11/2009	1.4	100	11.0%	32.0%	57.0%	43.0%
14	Winter-04	2/11/2009	1.6	103	11.7%	44.4%	43.9%	56.1%
15	Winter-05	2/23/2009	2.2	81	7.4%	34.0%	58.6%	41.4%
16	Winter-06	2/27/2009	1.4	91	12.1%	45.6%	42.3%	57.7%
17	Winter-07	2/27/2009	2.7	94	9.7%	52.4%	37.9%	62.1%
18	Winter-08	3/4/2009	1.3	114	0.0%	43.9%	56.1%	43.9%
19	Winter-09	3/4/2009	1.6	116	2.6%	32.4%	65.0%	35.0%
20	Winter-10	3/6/2009	2.5	87	6.9%	54.1%	39.0%	61.0%
21	Winter-11	3/11/2009	3.3	114	8.4%	38.3%	53.3%	46.7%
22	Spring-01	4/17/2009	1.9	78	2.6%	49.0%	48.4%	51.6%
23	Spring-02	4/17/2009	2.0	76	2.6%	26.3%	71.1%	28.9%
24	Spring-03	4/20/2009	2.7	95	2.1%	67.2%	30.7%	69.3%
25	Spring-04	4/24/2009	2.3	85	2.4%	63.9%	33.7%	66.3%
26	Spring-05	4/29/2009	2.1	108	8.8%	55.3%	35.8%	64.2%
27	Spring-06	5/1/2009	1.8	80	7.5%	49.4%	43.1%	56.9%
28	Spring-07	5/13/2009	2.4	103	2.0%	62.0%	36.1%	63.9%
29	Spring-08	5/13/2009	2.2	102	2.0%	55.2%	42.9%	57.1%
30	Spring-09	5/15/2009	1.4	81	14.9%	60.9%	24.2%	75.8%
31	Spring-10	5/20/2009	1.4	91	4.4%	41.8%	53.8%	46.2%
32	Spring-11	5/20/2009	1.4	91	11.1%	37.0%	51.9%	48.1%
33	Spring-12	5/27/2009	1.8	78	10.3%	50.0%	39.8%	60.2%
34	Spring-13	6/1/2009	1.1	85	2.4%	37.7%	60.0%	40.0%
35	Spring-14	6/3/2009	2.1	85	11.8%	42.4%	45.9%	54.1%
36	Spring-15	6/3/2009	1.1	81	2.5%	21.1%	76.4%	23.6%

Appendix C—Overview Table of Activities in Traditional Classroom

Activity Number	Activity Name	Date	Interaction Time (minutes)	Number of Students on Camera	Percent Active	Percent Mix	Percent Passive	Percent Participants (Active + Mix)
1	Fall-01	10/8/2008	5.1	81	2.3%	86.8%	10.9%	89.1%
2	Fall-02	10/10/2008	5.5	71	12.0%	53.5%	34.5%	65.5%
3	Fall-03	10/13/2008	1.9	70	8.6%	78.6%	12.9%	87.1%
4	Fall-04	10/15/2008	4.4	89	2.3%	71.2%	26.6%	73.4%
5	Fall-05	10/15/2008	1.6	90	15.6%	56.7%	27.7%	72.3%
6	Fall-06	10/17/2008	5.3	64	6.3%	77.1%	16.6%	83.4%
7	Fall-07	10/20/2008	1.6	81	45.7%	46.9%	7.4%	92.6%
8	Fall-08	10/24/2008	0.6	64	35.6%	44.2%	20.2%	79.8%
9	Fall-09	10/27/2008	1.2	81	0.0%	33.7%	66.3%	33.7%
10	Fall-10	10/27/2008	1.2	82	23.3%	46.0%	30.7%	69.3%
11	Winter-01	2/4/2009	1.5	71	8.5%	44.0%	47.5%	52.5%
12	Winter-02	2/6/2009	2.1	53	3.8%	56.6%	39.7%	60.3%
13	Winter-03	2/11/2009	1.4	66	3.1%	19.9%	77.1%	22.9%
14	Winter-04	2/11/2009	2.2	68	0.0%	48.5%	51.5%	48.5%
15	Winter-05	2/23/2009	2.4	47	1.0%	58.5%	40.4%	59.6%
16	Winter-06	2/27/2009	1.9	33	13.6%	28.8%	57.6%	42.4%
17	Winter-07	2/27/2009	2.1	33	6.1%	48.5%	45.5%	54.5%
18	Winter-08	3/4/2009	0.9	62	3.3%	17.8%	78.9%	21.1%
19	Winter-09	3/4/2009	4.3	63	3.2%	39.7%	57.1%	42.9%
20	Winter-10	3/6/2009	6.4	47	4.3%	53.2%	42.6%	57.4%
21	Winter-11	3/11/2009	2.2	56	3.6%	32.1%	64.3%	35.7%
22	Spring-01	4/17/2009	1.5	35	0.0%	37.1%	62.9%	37.1%
23	Spring-02	4/17/2009	1.5	36	11.1%	27.8%	61.1%	38.9%
24	Spring-03	4/20/2009	2.4	48	0.0%	54.2%	45.8%	54.2%
25	Spring-04	4/24/2009	1.5	37	10.8%	35.1%	54.1%	45.9%
26	Spring-05	4/29/2009	3.5	48	22.9%	27.1%	50.0%	50.0%
27	Spring-06	5/1/2009	1.3	30	0.0%	20.3%	79.7%	20.3%
28	Spring-07	5/13/2009	1.1	41	4.9%	37.8%	57.3%	42.7%
29	Spring-08	5/13/2009	0.9	42	9.5%	23.8%	66.7%	33.3%
30	Spring-09	5/15/2009	1.1	42	6.3%	37.5%	56.3%	43.8%
31	Spring-10	5/20/2009	1.2	39	5.1%	12.8%	82.1%	17.9%
32	Spring-11	5/20/2009	1.5	39	5.1%	20.5%	74.4%	25.6%
33	Spring-12	5/27/2009	1.9	43	0.0%	16.3%	83.7%	16.3%
34	Spring-13	6/1/2009	0.7	40	0.0%	15.0%	85.0%	15.0%
35	Spring-14	6/3/2009	0.7	32	6.3%	6.3%	87.5%	12.5%
36	Spring-15	6/3/2009	0.8	33	6.1%	15.2%	78.8%	21.2%

Appendix D—Overview Table of 12 Transcribed Activities

Activity Name	Classroom	Term Average Percent Participants	Term Std. Dev. Percent Participants	Percent Participants for this Activity	Participation Classification
Fall-03	Remodeled	70.3%	8.2%	**83.3%**	Very High
	Traditional	74.6%	16.9%	**87.1%**	Very High
Fall-07	Remodeled	70.3%	8.2%	**67.3%**	Low
	Traditional	74.6%	16.9%	**92.6%**	Very High
Fall-08	Remodeled	70.3%	8.2%	**66.5%**	Low
	Traditional	74.6%	16.9%	**79.8%**	High
Fall-09	Remodeled	70.3%	8.2%	**58.8%**	Very Low
	Traditional	74.6%	16.9%	**33.7%**	Very Low
Winter-02	Remodeled	50.8%	9.3%	**60.8%**	Very High
	Traditional	45.3%	13.8%	**60.3%**	Very High
Winter-03	Remodeled	50.8%	9.3%	**43.0%**	Low
	Traditional	45.3%	13.8%	**22.9%**	Very Low
Winter-05	Remodeled	50.8%	9.3%	**41.4%**	Very Low
	Traditional	45.3%	13.8%	**59.6%**	Very High
Winter-09	Remodeled	50.8%	9.3%	**35.0%**	Very Low
	Traditional	45.3%	13.8%	**42.9%**	Low
Spring-02	Remodeled	53.8%	14.6%	**28.95%**	Very Low
	Traditional	31.7%	14.0%	**38.89%**	High
Spring-03	Remodeled	53.8%	14.6%	**69.31%**	Very High
	Traditional	31.7%	14.0%	**54.17%**	Very High
Spring-12	Remodeled	53.8%	14.6%	**60.25%**	High
	Traditional	31.7%	14.0%	**16.29%**	Very Low
Spring-15	Remodeled	53.8%	14.6%	**23.60%**	Very Low
	Traditional	31.7%	14.0%	**21.21%**	Low