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Teacher Effects on Student Motivation during Cooperative Learning: Activity Level, Intervention Level, and Case Study Analyses

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In three cooperative learning studies, teacher interventions influenced student motivation, which in turn affected group outcomes. Forty students from five 9th grade classes were videotaped while solving an algebra problem together in groups of four. A teacher and a teaching assistant (TA) taught these classes and intervened 54 times. Controlling for past student achievement, higher student motivation increased cooperative problem solving success in the first study. In the second study, increased student autonomy and greater teacher responsiveness to students increased student motivation. Indicators of greater student autonomy included: student-initiated interventions, % of student talk and % of teacher/teaching assistant (T/TA) questions. Indicators of greater teacher responsiveness included % of T/TA support and % of T/TA criticism. Also, % of T/TA closed questions and % of T/TA compliments positively predicted student motivation. Finally,

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the case study discusses one intervention in detail, showing some conditions of use, exceptions to the above effects, and specifying how a compliment helped increase student motivation.

Key words: group work; classroom teaching; student motivation

Motivation is central to student achievement. Motivated students devote more time, effort and resources to learn and to solve problems. As a result, they perform better than their less motivated peers (Ames & Ames, 1984, 1985; Stipek, 1988; Wentzel, 1994). Researchers have argued that many factors can improve student motivation (e.g., a challenging complex problem [Stodolsky, 1988], a caring classroom environment [Caballo and Terrel, 1994], etc.). In particular, researchers have argued that both teachers (Ames & Ames, 1985; Brophy, 1983) and cooperative learning (Caballo & Terrel, 1994; Slavin, 1990) can improve student motivation. This article examines how teachers' interactions with students during cooperative problem solving increased (or decreased) students' motivation. By identifying effective and ineffective intervention methods, educators can improve student motivation and learning. This article presents three studies of videotape and statistical analyses of 40 students, five teacher/teaching assistants (T/TA) and their teacher/teaching assistant interventions (TI).

This article is organized as follows. The theoretical section reviews research on factors that improve student motivation. Three studies follow, regarding group solution outcomes, student motivation after a teacher intervention, and a case study of a teacher intervention. After a general discussion of the results, the paper concludes with some limitations and recommendations for future research.

Conceptual Perspective

Past research showed that greater teacher engagement and student autonomy both increase student motivation. However, these two factors can conflict if the teacher's assistance is unsolicited. To avoid this conflict, a teacher can let students ask for help and respond accordingly.

Teacher Engagement

Skinner and Belmont (1993) showed that teachers who devoted more time, affection and resources to their students (rather than rejection and neglect) increased their students' motivation throughout the school year. Likewise, researchers have shown that teacher guidance and explanations improve student motivation (see Brophy's [1986] review).

Student Autonomy

Giving students greater autonomy also increases their motivation. Instead of being told what to do or how to do it, students prefer greater leeway to choose and to make decisions (Chiu, in press). Moreover, students with greater autonomy are more motivated because their motivation is intrinsic. In contrast, extrinsic motivation through reward structures eventually undermines itself as students view the reward as more important than their activity (see reviews by Brophy [1986] and Grolnick, Ryan, & Deci [1989]).

At the utterance level, teachers can increase student autonomy by inviting their participation with questions rather than demanding it with commands (Chiu, in press). Questions show a knowledge gap and give students more leeway to answer. In contrast, commands specify actions for students to implement.

Teachers can also use closed or open questions. Closed questions have a narrow focus and typically have one correct answer. Open questions, however, are broad, and the answers' specificity and displays of understanding can vary widely. Researchers have argued that teachers allow students more freedom with open questions and constrain them with closed questions (Buzzelli, 1996; Greenberg, Woodside & Brasil, 1994). Furthermore, scaffolding advocates (Rogoff & Gardner, 1984; Wood, Bruner & Ross, 1976) argued that teachers must adapt their questions to the students' responses. After giving students wide leeway with an open question, teachers can use closed questions to address students' needs.

Excessive teacher engagement can also reduce students' self-confidence and motivation by encroaching on their autonomy. In particular, unsolicited teacher help can harm students. These students may view the teacher's help as necessary because they have low ability (Graham, 1990). Cohen (1994) further argued that a teacher should only intervene in student cooperative learning when the group is off-task or involved in an interpersonal conflict. At other times, she argued, the students should retain their autonomy and rely on themselves rather than become dependent on the teacher. By relying on themselves, the students avoid the false failure of asking for unnecessary teacher help. Then, they can increase their confidence by successfully solving the problem on their own.

Teacher Responsiveness

To maintain both teacher engagement and student autonomy, a teacher should respond to students' requests for help. Responsiveness includes both listening to students' utterances and evaluating them. Keller (1983) argued that teachers increase students' motivation by listening to them and providing relevant feedback. Brophy (1983) claimed that supporting students contingently (as opposed to undeserved praise and compliments) highlights students' competencies and focuses their attention on their task-relevant behaviors.

Excessive praise for simple tasks and avoidance of criticism for student failures can also have harmful effects. Graham (1990) showed that 11-12 year old students believe that effort is inversely related to ability. She also showed that they believe praise and criticism are indicators of effort and inverse indicators of ability. Students expect their teacher to praise them when they are exerting effort at the limits of their abilities. A teacher who praises students on simple tasks implies that they have reached the limits of their low abilities. Consequently, Graham (1990) argued that teachers should not bias their evaluations toward praise. Instead, they should criticize students for failures and avoid praise for successes on easy tasks.

In short, a teacher can increase student motivation by giving them some autonomy and by responding to their requests for help.

The remainder of this article reports three sets of analyses as separate studies on group solutions, student motivation after a teacher intervention and an intervention case study.

Study 1: Predicting Group Solutions

Hypotheses

As discussed earlier, motivated students should be more successful than less motivated students. Furthermore, students with past mathematics achievements are more likely to be successful in the current mathematics task. This study tests if these hypotheses are also true for groups.

- Group motivation and past mathematics achievement predict group solution success.

Method

The effects of students' motivation level on problem solving were tested by videotaping students' group problem solving, transcribing the videotapes, coding the videotapes and transcripts, and performing hierarchical regressions.

Participants

This study was part of a larger project in which we videotaped ethnically diverse students (38% African-American, 32% Euro-American, 20% Asian-American and 10% Latino-American) during their five algebra classes for six weeks. Two teachers and three teaching assistants (TA) taught the classes in an urban, public high school in the United States of America. There were one teacher and one TA per class. All teachers and TAs were Euro-American. The teachers randomly assigned students into groups, and the students did not receive any cooperative learning training. The teachers had taught for 10 and 11 years, and the TAs were education doctoral candidates with 2-5 years of teaching experience. The ten videotapes were of 40 students (ten groups of four) across five classes doing one lesson near the end of a six-week unit on functions.

Procedure

After a teacher introduced the following problem below in each class, the student groups worked on it for 20 minutes while the teacher and TA monitored their progress with occasional interventions:

> Nintendo charges $180 for each gaming system and $40 for each video game. Sega charges $120 for each gaming system and $50 for each video game. How many games must a customer buy to pay less for Nintendo than for Sega? (Note: customers must buy a gaming system before buying any video games.)

The team of teachers and researchers believed that this was a difficult problem for these students even though they had covered enough mathematical concepts and relationships in class to solve it. There were algebraic, graphical and tabular methods for finding the critical number of games in which the cost is the same for either brand. Then, the correct answer is obtained by adding an additional game so that the cost of buying Sega exceeds that of buying Nintendo.

Using equations, students could set the cost equations equal to each other and solve for the number of games (g): $180 + 40g = 120 + 50g \rightarrow 60 = 10g \rightarrow 6 = g$. Using a graph, students could graph each equation and find the intersection of the lines. X is the number of games, and y is the total cost. For Nintendo, $y = 180 + 40x$. For Sega, $y=120 + 50x$. Graphing the two lines yields an intersection point of $(x,y) = (6, 420)$. Thus, the cost for 6 games is $420 for both companies. With a table, students can add additional games and compute the cost until the costs are equal (see table 1). Adding one to the number of games, 6, yields the final answer, 7.

Table 1 A table solution created by adding the cost of successive games (Nintendo: 40; Sega: 50)

Games	Nintendo Cost	Sega cost
0	180	120
1	220	170
2	260	220
3	300	270
4	340	320
5	380	370
6	420	420
7	460	470

Variables

Solution score. Each group was given a score (0-3) based on their problem solving outcome: correct solution (3), correct method (2), correct understanding of the problem situation (1), or none of these (0). See Appendix for coding details.

Past mathematics achievement. The students' mid-year algebra grades were used to compute the mean grade for each group.

Student motivation. Because each student in a group must be coded for their motivation at different times, the problem solving sessions were divided into one minute intervals. For each minute of cooperative learning, we coded each student's motivation level as either motivated, unmotivated, or distracting, respectively 1, 0, and -1. *Motivated* was operationally defined as student behaviors that showed desire to work on and to solve the problem. They included encouraging others to work on the problem, showing enthusiasm for the work, listening intently to solution proposals, discussing it, etc. Students' motivation levels were coded as *distracting* if their behaviors discouraged others from working on the problem. Distracting behaviors included denigrating the task or asking off-task questions to other group members. Finally, the students were coded as *unmotivated* if they were neither motivated nor distracting, for example, looking out the window. See Appendix. Each group motivation score was the mean of all of its members' motivations.

Analysis

The correlation between mean mathematical grade for each group and their mean motivation was tested for significance. Then, controlling for mathematical grade, the significance of the correlation between mean motivation and final solution score was tested.

Videotaping, Transcription and Coding

The groups of students and the teachers were each videotaped separately. The teacher intervention segments of the student videotapes for each class were fully transcribed for words and gestures (McNeil, 1992). The teacher videotapes were used to triangulate transcription of poor sound quality segments. Two people coded each variable. For student motivation, each coder made a separate pass through each transcript for each student. For each remaining variable, each coder made a single pass through each transcript (see Chiu, in press). Cohen's kappa computations tested inter-rater reliability.

All results were significant at the .05 level.

Results

The students found this problem difficult as only half of the groups correctly solved it (see table 2). Of the 784 student-minutes coded for motivation, students were motivated 63% of the time, unmotivated 19% of the time and distracting 18% of the time (Cohen's kappa = .88, $p < .001$). (There were 16 student-minutes that could not be coded because of poor sound quality. None of these occurred during the teacher interventions.)

Table 2 Summary statistics at the activity level

Variable	Mean	Std Dev	Minimum	Maximum
Final solution score	1.8	1.3	0	3
Mean math grade	79	7	71	89
Mean student motivation	.18	.36	-.40	.67

Mean student motivation predicted the group's final solution score. As expected, mean mid-year mathematics grade significantly correlated with mean group motivation ($r = .48$, $\underline{p} < .05$). After controlling for grade, group mean motivation also significantly correlated with solution score ($r = .69$, $\underline{p} < .05$).

Discussion

These results showed that group motivation affects the group outcome, consistent with research showing that individual motivation affects individual outcomes (Ames & Ames, 1984, 1985; Stipek, 1988; Wentzel, 1994). Having shown that motivation was an important factor in the group solution scores, consider the effect of teacher interventions on student motivation.

Study 2: Predicting Student Motivation after a Teacher Intervention

Hypotheses

Properties prior to the teacher intervention can influence students' subsequent motivation. In particular, the students' motivation and problem solving progress before the T/TA intervention (TI) can affect their motivation afterwards. If students were already motivated, they were likely to remain motivated. Also, groups who have already made some progress can be more motivated than those that have not. However, research has shown that past student achievement did not predict motivation at the macro-level (Crandall, 1969; Stipek & Hoffman, 1980). This study tests this hypothesis at the micro-level.

- Higher pre-TI student motivation predicts higher post-TI student motivation.
- Greater pre-TI student problem solving progress does <u>not</u> predict higher post-TI student motivation.

As discussed earlier, teacher behaviors that encourage student autonomy or are responsive to students' needs should increase student motivation. During cooperative learning, teachers can wait for students to initiate discussions and avoid dominating the conversation in both quantity (words) and quality (content).

- Student-initiated interventions predict higher post-TI student motivation.
- Greater quantity and quality of teacher involvement predict lower post-TI student motivation.

Teachers can also choose particular speech forms to encourage student autonomy. Teachers can ask more questions, especially open questions, rather than issue commands. According to scaffolding advocates, open questions should precede closed questions.

- Teacher commands predict lower post-TI student motivation.
- Teacher questions, particularly open questions, predict higher post-TI student motivation.
- Teacher open questions preceding closed questions predict higher post-TI student motivation.

Teachers can also increase student motivation by remaining responsive to students, listening and evaluating without bias toward supportive actions or against criticism:

- Responsive supportive actions and criticisms predict higher post-TI student motivation.
- Non-contingent praise or compliments does <u>not</u> predict higher post-TI student motivation.

Method

Participants and Procedures

Same as study 1.

Variables

The following variables were used in addition to those in study 1.

Problem solving progress. Before each TI, the group's problem solving progress (0 - 3) was coded with the same scoring system as the variable "solution score" in study 1.

Words. To measure the quantity of interaction, the total number of words spoken by all participants during a TI was counted, and the percentage of words spoken by the T/TA was computed. Measuring time rather than words underestimates the effect of faster-speaking people. Likewise counting speaker turns underestimates the effect of long turns.

Initiation of T/TA intervention. Either a student (0) or a teacher (1) initiated each TI.

T/TA content. During an intervention, a T/TA may give no solution information (0), draw attention to a part of the problem or the students' solution (1), provide part of the solution (2), or demonstrate the entire solution (3).

T/TA evaluations. A T/TA can support, criticize or ignore the last speaker (Chiu, in press). The percentage of T/TA support per TI was computed as follows: # supportive T/TA turns ÷ # total T/TA turns. Percentage of T/TA criticism was computed in a similar manner. See Appendix for coding details.

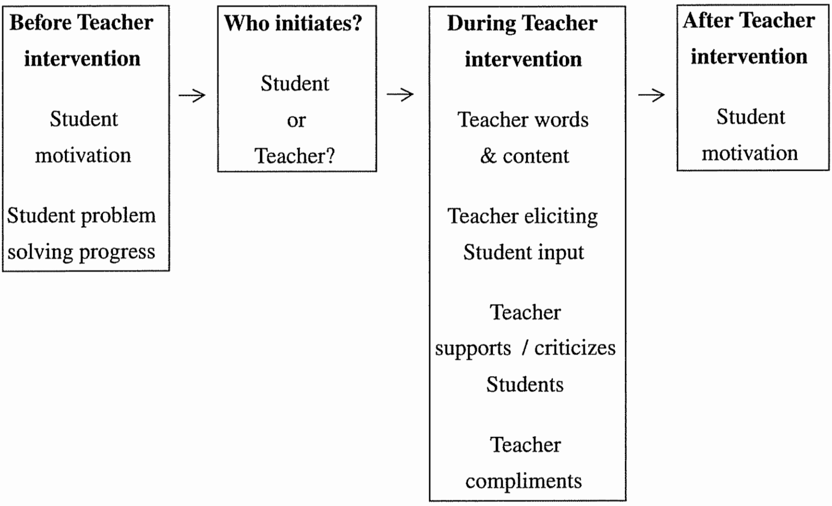
T/TA speech forms. T/TAs can use commands, questions or statements to address students (Chiu, in press). Percentages of T/TA commands and questions were computed in the same manner as percentages of T/TA supportive actions above. Percentage of T/TA open questions per TI was computed as follows: # T/TA closed questions ÷ # total T/TA questions. Also, the "open before closed" variable measured whether a T/TA's open question (s) preceded at least one closed question (1), whether closed questions preceded all open questions (-1), or neither (0).

T/TA compliments. Compliments are attributions of a person such as "good thinking" and differ from evaluations of solutions such as "correct." TIs can include T/TA compliments (1), T/TA insults (-1), or neither (0).

Analysis

Figure 1 shows the temporal and causal relationships in my model. Pre-TI factors influence who initiates the TI, which, in turn, influence the actions during the TI which affect post-TI student motivation. Before the TI, a group of students have a prior motivation level and a problem solving progress level. Next, either a student or a T/TA initiates a TI. During that TI, the teacher uses specific behaviors while interacting with the students, all of which may affect student motivation after the teacher leaves the group.

Figure 1 Temporal and causal relationships in my model of effects on student motivation as a result of a teacher intervention.



In short, the hierarchical regression and path analyses predicted post-TI student motivation with: (a) pre-TI student motivation and problem solving progress, (b) student or T/TA initiation, (c) % of TI words by T/TA, T/TA content, % of T/TA questions, % of T/TA commands, % of T/TA closed questions, T/TA open questions before closed questions, % of T/TA support, % of T/TA criticism and % of T/TA compliments.

Results

The T/TAs intervened in the students' group problem solving 54 times, speaking for 269 turns. As shown in table 3, TIs alone did not significantly increase student motivation. The mean motivation increase was from .18 to . 19, paired t-test = .69, p > .10 (kappa = .91, p < .001). T/TA actions included 41% questions, of which 76% were closed, 22% commands and 37% statements, (kappa = .96, p <.001). The T/TA turns were 33% support, 44% criticism, and 23% neither (kappa = .89, p <.001). T/TAs complimented students on 3% of their turns (kappa = 1, 100% agreement). Surprisingly, there were two instances in which a teacher insulted a student, with predictably negative effects on student motivation.

Table 3 Summary statistics at the intervention level

Variable	Mean	Std Dev	Mininum	Maximum
Number of interventions per group	5.4	2.8	2	10
Student motivation after Teacher intervention	.19	.83	-1.00	1.00
Student motivation before Teacher intervention	.18	.78	-1.00	1.00
Student problem solving progress	.89	.88	0	2
Teacher initiates	.74	.44	0	1
% Teacher supports	.33	.48	.00	1.00
% Teacher criticizes	.44	.50	.00	1.00
Total Words	147	1277	4	557
% Words by Teacher	.45	.24	.05	.96
Teacher content	.70	.82	0	2.00
% Teacher questions	.41	.35	.00	1.00
% Teacher commands	.22	.37	.00	1.00
% Teacher questions, closed	.76	.30	.00	1.00
Teacher questions - open before closed	.39	.53	-1.00	1.00
Teacher compliments	.15	.45	-1.00	1.00

The hierarchical regressions show that percentages of T/TA questions, support, criticism and compliments positively predicted post-TI student motivation (see table 4). Meanwhile T/TA initiation, % T/TA words, and % T/TA open questions negatively predicted it. Pre-TI student motivation, pre-TI problem solving progress, T/TA content, and T/TA open before closed questions showed no significant effects.

The path analysis in figure 2 showed that T/TA-initiated TIs have a further negative indirect effect on student motivation. This negative effect occurs through % T/TA words and % T/TA criticisms, partially offset by % T/TA supportive actions. When a T/TA initiated the intervention, they talked more relative to the students, made more supportive comments and made fewer critical comments.

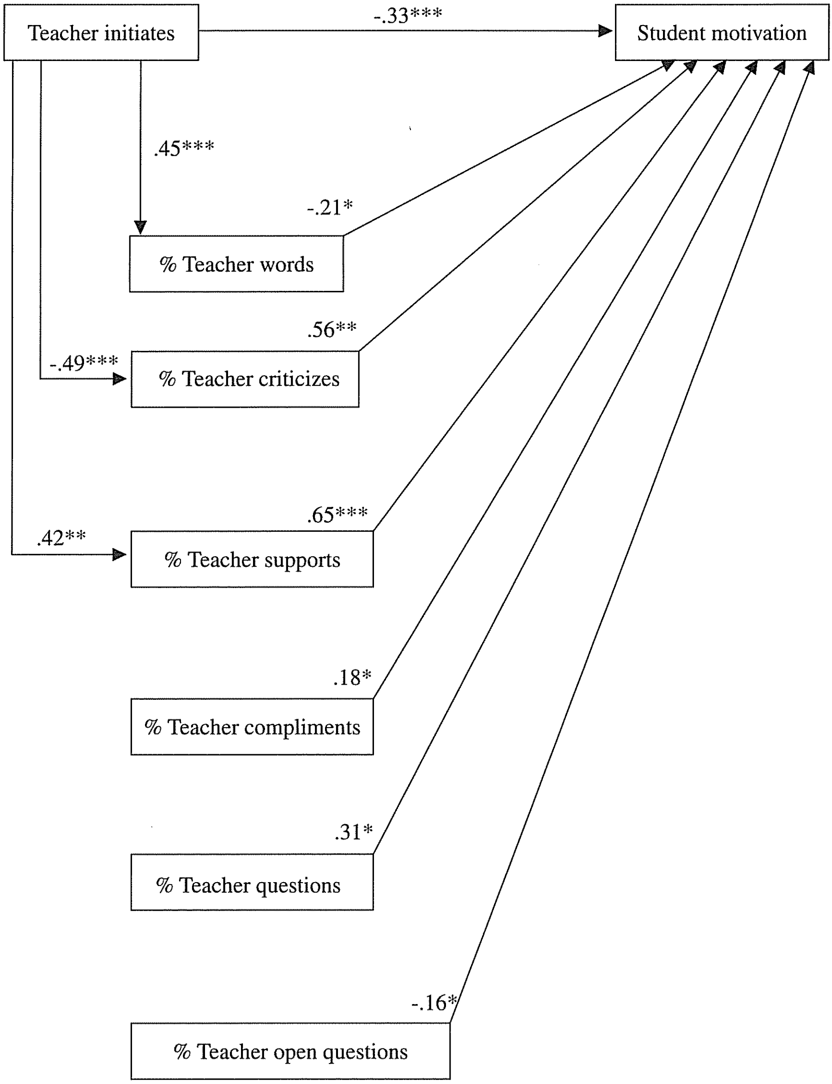
Table 4 Hierarchical regressions predicting student motivation after a teacher/TA intervention (TI): regression coefficients (with standard errors in parentheses).

	Regressions				
Predictors	1	2	3	4	5
Pre-teacher intervention	-.202	-.179		-.044	
Motivation	(.139)	(.130)	(.088)		
Pre-teacher intervention	.108	.060		-.136	
Problem Solving Progress	(.179)	(.170)	(.142)		
Teacher-initiated		-.367**	-.402***	-.404**	-.326***
intervention		(.124)	(.116)	(.152)	(.084)
% of words by teacher			-.224*		-.209*
			(.105)		(.094)
Teacher content			.166		
			(.094)		
% Teacher questions			.408*		.314*
			(.161)		(.141)
% Teacher commands			.270		
			(.258)		
% Teacher open questions			-.222*		-.157*
			(.106)		(.068)
Teacher uses open then			.012		
closed questions			(.146)		
Teacher supports			.812***		.653***
			(.183)		(.150)
Teacher criticizes			.917***		.557***
			(.221)		(.110)
Teacher compliments			.222*		.177*
			(.101)		(.075)
R^2	.08	.21**	.80***	.16**	.77***
Adjusted R^2	.04	.16**	.74***	.14**	.72***

Discussion

The pre-TI factors, student motivation and problem solving progress, did not significantly affect post-TI student motivation. These results suggest that teacher interventions can have a strong effect on student motivation. Over 60% of the post-TI student motivation variance (R^2) is explained by

Figure 2 Path analysis of the significant predictors of student motivation after Teacher/TA intervention.



significant teacher behavior variables during the TI. The insignificant prob lem solving progress result at the micro-level is also consistent with macro-level research showing that past achievement does not predict motivation (Crandall, 1969; Stipek & Hoffman, 1980).

The results also supported the arguments for student autonomy by showing that post-TI student motivation increased after TI's in which (a) students initiated the TI, (b) teachers talked proportionately less and (c) the T/TA asked proportionately more questions to invite student participation. All of these behaviors allowed students more leeway to make decisions and hence, increased their motivation.

Teacher responsiveness also increased student motivation as % T/TA supportive actions and % T/TA critical actions both increased post-TI student motivation. This result supports the view that students appreciate teachers listening to students and providing feedback, regardless of its supportive or critical nature.

Surprisingly, percentage of T/TA open questions had a negative effect on student motivation, and T/TA compliments showed a significant, positive effect on student motivation. The following case study examines an intervention with a closed question and a compliment in greater detail.

Study 3: A Case Study of an Intervention

In this case study drawn from the above data, consider how a TA facilitated a student group's (PA, KA, LO, and EM) problem solving with a compliment. PA had been dominating the conversation with disruptive questions about KA's personal life. KA and LO had also engaged in off-task conversations, but EM had been silent for the entire group problem solving session thus far (eight minutes). In the midst of an off-task conversation, TA walked by the group.

[1:03:18 - 1:05:11]

LO: Let me see your ruler. [takes ruler from KA's side of the table]

TA: [walks by the group, leans in behind LO and EM, smiles] You guys got an answer yet?

PA: No.

LO: We're just starting.

TA: [looks at LO's paper] Well, I see somebody doing at least the graph part right, anyways.

PA: Yeah, it looks just like mine. [PA has not drawn a graph]

TA: [Smiles at PA] That's a nice shirt, by the way, that you have on.

PA: Thank you.

TA: You're welcome.
[TA leaves.]

LO: I got a five games thing. Is it like a five thing? It's like 10, 20, 30, 40 like that? [while counting, his right hand bounces along his graph]

KA: I guess, it's like 10, 20, 30, 40. Do a table for it.

LO: What about for the top one? You know, it's by ones, right? It's like 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

EM: This is for games? [points with pencil to paper]. Then what's this?

PA: You have money, it's for games. This is for one, this is for two [PA's finger taps EM's paper]

TA's brief social interaction had a dramatic effect on the group: PA started working on the problem, LO initiated a problem topic, and EM spoke for the first time this period. Initiating the intervention, TA asks a simple, closed question to engage the students, "got an answer yet?" (As noted earlier [Cohen, 1994], teacher-initiated interventions are appropriate when students are off-task.) Then, TA learned that they made little progress, "No," "We're just starting." Yet, he did not intrusively engage them with a command or with probing questions. Instead, he highlighted desirable productive behavior by praising LO's graph, "I see somebody doing at least the graph part right." Despite his recent disruptive behavior, PA accepted this standard of assessment and drew attention to himself by falsely claiming credit for a similar graph, "it looks just like mine." Rather than challenging the validity of PA's claim, TA complimented him on his shirt, "[smiles at PA] That's a nice shirt". PA accepted this praise, "thank you," and started working on the problem. Shortly after TA left, LO capitalized on TA's validation of his graph to initiate a discussion of it. KA, EM, and PA all engaged in the conversation, initiating proposals or questions.

In this episode, TA's compliment served a particular purpose: he satisfied a student's specific bid for attention without compromising his mathematical standard of evaluation. After showing approval of a student's productive work, the TA did not lower his mathematical standard to praise a student who had not done the work. He also did not reject the student's bid for attention by criticizing him. Instead, he showed his social affiliation with the student by complimenting him outside of mathematics, on the student's sartorial judgment. Moreover, TA only complimented the student who bid for attention. He did not dilute the compliment's value by praising others who did not ask for attention.

General Discussion

These three studies showed how teacher interventions affected students' motivations, which in turn affected their problem solving outcomes. The first study showed that, controlling for past achievement, motivation affects problem solving outcomes in groups of students as well as in individual students, consistent with earlier studies (Ames & Ames, 1984, 1985; Stipek, 1988; Wentzel, 1994).

Having established the importance of motivation, the second micro-level study showed how teacher interventions affected student motivation. Not all teacher interventions increased student motivation. Some did, some did not. It depended on the specific teacher behaviors during the interventions. Teacher behaviors that encouraged student autonomy and showed responsiveness increased student motivation, consistent with macro-level studies (Brophy, 1986; Grolnick, Ryan, & Deci, 1989). Teacher behaviors encouraging student autonomy included: letting students initiate the intervention, letting students talk more, and asking students questions, particularly closed questions. When a teacher was responsive to the students, he or she listened to them and supported or criticized their ideas.

Surprisingly, teacher closed questions increased student motivation more than teacher closed questions, unlike earlier studies (Buzzelli, 1996; Greenberg, Woodside & Brasil, 1994). One possible explanation is that teacher questions during a class discussion differ from those during cooperative problem solving. During a class discussion, a teacher can use an open question to frame the discussion. During a group problem solving activity however, there is an open question already, namely the problem. If students are having difficulty, they are likely to need help in a specific area. So, a closed, targeted question can address their immediate concerns more readily than an open question. The case study also showed how a teacher used a simple, closed question to engage off-task students.

Compliments also unexpectedly increased motivation. Note however, that there were few compliments during TIs, less than one T/TA compliment for every six TIs. This infrequent use suggests that its effectiveness is limited to specific situations such as an off-task student, as shown in the case study.

Limitations and Future Research

Many questions still remain. First and foremost, can these results be replicated with larger and more diverse samples? Are there more precise methods of measuring processes during teacher interventions? Do these teacher behaviors yield similar results when students collaborate on less defined problems or tasks in different subjects? Do successful teachers adapt their interventions to different students? If so, what are the different types of interventions? What criteria do they use to effectively characterize each situation – problem solving progress, level of students' social interaction, and/or past student achievement? By answering these questions, educators can help students work together more productively.

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Appendix : Coding Motivation, Solution Score and Speaker Turns

Motivation:

For each one minute segment:

Does the student want to work on the problem?

Yes, code as *motivated*

No, is the student discouraging others from working on the problem?

Yes, code as *distracting*

No, code as *unmotivated*

When a student showed different levels of motivation within a one minute segment, a weighted average of the students motivation level was computed (to the nearest second).

Solution score:

Correct answer:	3 points
Articulated a correct solution method:	2 points
Articulated the correct goal and problem situation:	1 point

Goal:

Finding the critical number at which the cost for each product is identical

Problem situation:

Cost is computed by price of system plus price of each game. Each company has different prices for their system and their games

None of the above:	0 points

Code each speaker turn along the 3 following dimensions:

Evaluation:

Does the speaker respond to the previous speaker?

- No, code as *unresponsive*
- Yes, does the speaker fully agree with the previous speaker?
  - Yes, code as *supportive*
  - No, code as *criticism*

Invitational form:

Does the speaker demand action (or inaction) from one or more listeners?

- Yes, code as *command*
- No, does the speaker ask someone to participate?
  - Yes, code as *question*
    - Can the question be answered correctly in less than 5 words?
      - Yes, code as *open question*
      - No, code as *closed question*
  - No, code as *statement*

Personal Judgment:

Does the speaker attribute a specific positive personal characteristic to a listener?

- Yes, code as *compliment*
- No, does the speaker attribute a specific negative personal characteristic to a listener?
  - Yes, code as *insult*
  - No, code as *non-personal*