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ABSTRACT

Eighty ninth graders who solved an algebra problem in groups of four showed status effects at the individual level. The students had filled out preactivity questionnaires about mathematical status and social status and a postactivity leadership questionnaire. Hierarchical regressions and path analyses show that, at the group level, solution score was predicted positively by mathematics grade, correct turns, supportive evaluations, and redressed criticisms (criticism that reduced blame and created common ground), and negatively by naked (blunt) criticisms. At the individual level perceived group status was predicted positively by social status, percentage of group's words spoken in the cooperative problem solving, and redressed criticisms, and negatively by naked criticisms. Social status positively predicted both percentage of group words and redressed criticism turns, while mathematical status positively predicted naked criticisms. In a separate regression, social status (but not mathematical status) positively predicted received supportive evaluations after controlling for correctness. These results also show how criticism can have conflicting effects on social and cognitive goals. Five appendixes contain the precollaboration questionnaire, one problem, the speaking turns coding system, and regression and path analysis results. (Contains 7 tables, 1 figure, and 18 references.) (SLD)

Status effects in group problem solving:

Group and individual level analyses

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Abstract

Eighty students solved an algebra problem in groups of 4 showed status effects at the individual level. The students filled out pre-activity questionnaires regarding mathematical status and social status and a leadership post-activity questionnaire. Hierarchical regressions and path analyses showed the following. At the group level, solution score was predicted positively by mathematical grade, correct turns, supportive evaluations, and redressed criticisms, and negatively by naked criticisms. The following are all individual level results. Perceived group leadership was predicted positively by social status, percentage of group's words and redressed criticisms, and negatively by naked criticisms. Social status positively predicted both percentage of group words and redressed criticisms turns whereas mathematical status positively predicted naked criticisms. In a separate regression, social status (but not mathematical status) positively predicted received supportive evaluations after controlling for correctness. These results also show how criticisms can have conflicting effects on social vs. cognitive goals.

Status effects in group problem solving:
Group and individual level analyses

Researchers have shown that collaborative group work can induce many beneficial outcomes (increase learning, decrease racial tension, promote positive student attitudes toward school, etc. [see reviews by Good, Mulryan & McCaslin, 1992; Slavin, 1990]). However, status researchers have also shown that the differential status of individuals affected their social interactions and their capacity to solve problems together (Berger, Cohen, & Zelditch, 1972; Meeker, 1981; St. John, 1996). As educators implement cooperative learning in classrooms, understanding the effects of status during group work can help teachers utilize beneficial status effects and counteract harmful ones. Through preliminary micro-analyses of twenty groups of high school students solving an algebra problem, I show how social and mathematics statuses influenced group problem solving success through specific individual actions.

Theoretical Perspective

Individual Status

Status differences among students can yield harmful effects for both lower status students and the group as a whole. Berger et al. (1972) argued that status affects the expectations of individual group members, which in turn entails differential opportunities to perform and subsequently receive rewards. In studies of student group work, Cohen (1984), Dembo and McAuliffe (1987), St. John (1996), and Tammivaara (1982) showed that higher status students interacted more and were more influential than lower status students. As a result, group members identified high status students as leaders more often (Dembo and McAuliffe, 1987).

With greater access to group resources and more feedback, higher status students also learned more (Cohen, 1984).

Status effects can harm the entire group by limiting lower status student participation and skewing evaluations. Through selective invitation, exclusion and deference, students can enact their expectations of participation dominated by high status students, thereby depriving themselves of lower status students' potential contributions (Cohen, 1994). Status differences can also skew evaluations when lower status students defer to higher status students or when higher status students downplay lower status students' contributions.

Status can also have multiple components such as social or academic status. According to Webster and Driskell (1983), social status can be based on perceived attractiveness and social popularity. Although Rosenholtz and Wilson's (1980) subjects' social and academic statuses correlated, St. John's (1996) subjects' social and academic statuses did not. Furthermore, she showed that her subjects' mathematical statuses correlated with participation and complexity of mathematical talk, but their social status did not.

Politeness in utterances

Researchers have examined help-related utterances (e.g., asking for it, giving it) during group work processes (Brown & Palincsar, 1989; King, 1990; Webb, Troper, & Fall, 1995), but they have not considered how the politeness of these utterances reflect status effects. Brown and Levinson (1987) argued that participants in a conversation seek to maintain a desirable public self-image, or "face." Conversely, they argued that direct face-threatening acts indicate vast differences in power (and status), minimal social distance (friends), or minimal impositions that benefit the listener ("come in"). By pursuing the social goal of maintaining face, students working collaboratively may facilitate or hinder attainment of their cognitive goal, solving a problem.

Consider how the politeness of each speaker's evaluation affects group participants' maintenance of face (Chiu, 1997). Listeners can respond to the previous speaker's utterance with agreement, neutrality, naked disagreement, redressed disagreement or unresponsiveness. A listener agrees with the previous speaker using a supportive utterance ("yeah"). A person can also try to remain neutral ("let me think about that"). However, the previous speaker may treat a neutral response as implicitly critical and continue exploring additional methods of persuasion. Listeners can also disagree, either bluntly (naked criticism) or with redress (Brown & Levinson, 1987). Compare the naked criticism "you're wrong" with the redressed criticism "If six is multiplied by two, we don't get ten." This redressed criticism both reduces blame and creates common ground. The redressed criticism reduces blame by using: (a) a hypothetical to distance the idea from reality ("if"), (b) no reference to the previous speaker to avoid personal responsibility (no "you"), (c) passive voice to avoid agency ("is multiplied"), and (d) a passive circumstantial verb to implicate external circumstance ("get"). To create common ground, the redressed criticism uses: (a) repetition to show shared understanding ("six is multiplied by two ... ten"), and (b) shared positioning to claim common cause ("we"). Finally, the next speaker may initiate a new topic of conversation without evaluating the previous speaker's words (unresponsive).

In short, evaluations compose a scale of decreasing respectfulness: supportive, neutral , redressed criticism, and naked criticism.

Hypotheses

Next, consider the consequences of status and individual actions at the group and individual levels.

Group level: problem solutions

At the group level, these statuses and properties can affect the likelihood of a correct solution to a difficult, ill-structured problem. Academic status likely reflects academic ability and should predict correct actions and a problem solution. Meanwhile, social status may reflect social skills that can facilitate group participation and hence problem solving. Greater variance of mathematical status, social status, and perceived leadership indicates greater status disparity among the students and increases the likelihood of limiting lower status student participation and skewed evaluations. Total words spoken reflect degree of interaction and may correlate the group's solution score.

Knowledge content. Correct ideas and actions are the likely building blocks of a solution while even incorrect contributions (new ideas or actions) may facilitate a solution if they contain useful components.

Evaluation. Polite evaluations (supportive actions and redressed criticisms) encourage participation, thereby increasing potential contributions and the probability of a correct solution. Supportive utterances can build on the previous idea and motivate colleagues to participate but may also promote incorrect solution paths. Although redressed criticisms are less affiliative, they promote problem solving by identifying potential errors. In contrast, naked criticisms identify potential errors impolitely and discourage participation.

Group problem solving hypotheses:

- Mathematical grade, mathematical status, social status, number of words, correct actions, contributions, supportive actions and redressed criticisms positively predict group solution score.
- Mathematical status variance, social status variance, leadership concentration, and naked criticisms negatively predict group solution score.
- Mathematical grade predicts correct actions.
- Correct actions predict supportive evaluations.

Individual level: leadership, social status, mathematical status

Both social and mathematical status may predict leadership. High social status may reflect social skills that create leadership through polite actions (e.g. redressed criticism) rather than impolite actions (e.g. naked criticism). Mathematical grade and status should correlate with correct turns and contributions, hence constituting a claim to leadership. Students with high mathematical status but low social skills may also show their higher status with more impolite actions such as naked criticisms.

As with earlier studies, degree of interaction (percentage of group's words) should also predict leadership.

Status predicts participation and skews evaluations, so status should predict both percentage of group words and supportive evaluations from the following speaker (received support).

Individual level hypotheses:

- Mathematical status, mathematical grade, social status, percentage of group words and percentage of contribution turns positively predict leadership.

- Social status and mathematical status positively predict percentage of group words.
- Mathematical grade positively predicts correct actions.
- Social status positively predicts redressed criticisms and negatively predicts naked criticisms.
- Mathematical status positively predicts naked criticisms and positively predicts redressed criticisms.
- Social status, mathematical status and correctness all positively predict received support.

Figure 1 shows the temporal and causal relationships in my model. Pre-existing student properties before the group work affect their collaborative problem solving which in turn affects their perceptions of one another's leadership and the resulting solution. Prior student properties include mathematical ability, mathematical status, and social status. These three properties may change over time and vary in different situations, so their effects may only be local to the immediate problem. Collaboration variables include words, correctness, contributions, and evaluations.

Insert figure 1 about here

Methods

<u>Participants</u>

In four 9th grade algebra classes in an urban high school, 117 ethnically-diverse students answered pre- and post-questionnaires. I selected 80 students (20 groups of 4 students) to create counterbalanced groups with different combinations of mathematical ability. High ability students received mid-year math grades higher than 80 while low ability students scored lower than 80. None of the students in each group were friends, and they did not receive any group work training.

Procedure

During their algebra classes, I gave questionnaires to the 117 students who volunteered to be part of the study. This questionnaire had four questions regarding mathematical status and social status (see Appendix A). For each question, students listed three people in their class who they perceived as having high status (mathematical or social).

Then, their teacher presented the following problem in each of the algebra classes that the students tired to solve in groups for 30 minutes:

> You've won a cruise from New York to London, but you arrive 5 hours late and the ship has left without you. To catch the ship, you rent a helicopter. If the ship travels at 22 miles an hour and the helicopter moves at 90 miles an hour, how long will it take for you to catch the ship?

The classes had covered equations with single variables and the teacher used the problem to introduce them to algebraic equations with multiple variables. As a result, many of the students found this problem difficult, in part because there were complex mathematical relationships, non-trivial combinations of multiple operations, and a non-integer solution.

There are at least three possible solution methods (see Appendix B). Perhaps the simplest conceptually is equating the distance equations for each vehicle, cruise ship and helicopter,

$$22 \text{ mph } (\text{time} + 5 \text{ hours}) = 90 \text{ mph} \times \text{time}$$

to obtain 1.618 hours or 1 hour 37 minutes.

I videotaped the 80 students and transcribed the group work portions of the videotapes.

After the group work, I administered a leadership questionnaire to all 117 students individually, but only included the leadership results from the 80 selected students in my analyses. The leadership questionnaire asked:

Were there any leaders in your group?

If yes, please name them and give their leadership %.

Measures

Mathematics achievement. I used the students' mid-year algebra grades to compute the mean grade for each group.

Student statuses. I counted the number of times a videotaped student's name appeared in his or her classmates' answers to the two mathematics status questions to determine the students' mathematical status. Likewise, I determined a student's social status from the two social status questions. I also computed the mean social status, mean mathematical status, social status standard deviation, and mathematical status standard deviation for each group. (The standard deviations had normal distributions whereas the variances did not.)

Leadership. I computed the mean percentage of leadership attributed to each person. In addition, I created a group leadership concentration score by summing the squares of each person's mean attributed leadership (e.g., $.75^2 + .25^2 + 0^2 + 0^2 = .625$). The individual leadership distribution was positively skewed, so I applied a logarithmic transformation, $\ln(x + 1)$.

Coding

Words. I counted the total words for each group. In addition, I computed each person's percentage of group words (# person's words ÷ # group words). The total words and percentage of words had bi-modal distributions, so I converted the variables into boolean variables.

Solution score. Each group received a final solution score (0 -3) based on their problem solving progress (see Appendix B).

Speaker turn properties. A colleague and I coded each turn by the properties discussed earlier: correctness, contributions, supportive actions, received supportive actions, neutral actions, naked criticisms, and redressed criticisms (See Appendix D for coding.) (We only judged on-task speaker turns for correctness.) I computed Cohen's kappa for each dimension. In addition, I computed the percentage of each turn property per person (person's uses of property ÷ person's total turns) and per group. Then I applied a logit transformation on the percentages to reduce tail effects. Individual percentage group's words and percentage of individual's naked criticisms both showed bi-modal distributions so I converted them into dichotomous variables.

Levels of analysis

At both group and individual levels of analysis, I used hierarchical regressions to test for total effects and path analyses to test for direct and indirect effects with the same order of variables at each level (based on temporal order, causality, controlling for specific variables and their theoretical relative importance).

In this paper, "total β" refers to the standardized hierarchical regression coefficient, and "direct β" refers to the standardized simultaneous regression coefficient in which all variables in the regression specification are included.

Group level: predicting solution score

In the hierarchical regression and path analyses, I entered student properties before the collaboration activity. Mathematical ability typically predicted mathematical solutions positively and was assumed to be the dominant causal factor. Because researchers have not determined the relative importance of mathematical status, social status, and their standard deviations to the final solution, I entered them together after mathematical grade.

Next, I entered the collaboration variables: words, correctness, contributions, and evaluations. Total words alone may account for problem solving success regardless of their content and served as a control for the frequency of the remaining variables. Otherwise, percentage of correct turns should predict solution score. Of lesser importance was total contributions. Temporally, evaluations follow actions, so the percentages of supportive actions, redressed criticisms and naked criticisms were entered as a set afterwards. Finally, I entered concentration of perceived leadership which participants were likely to judge based on actions during the collaboration.

In short, the hierarchical regression and path analyses predicted solution score with groups': (a) mathematical grade, (b) social status, mathematical status, social status standard deviation, mathematical status standard deviation,[1] (c) total words, (d) percentage of correct turns, (e) total contribution turns, (f) percentage of supportive turns, percentage of naked criticisms, and percentage of redressed criticisms, and (g) perceived leadership concentration.

Individual level: predicting leadership and received supportive evaluations

Predicting leadership. Social status may reflect social skills and hence predict leadership more than mathematical ability would. Mathematical ability likely predicts mathematical status so those two are entered in that order. Next, I tested the quantity of interaction effect with the percentage of the group's words spoken by each group member. Then, I entered percentage of correctness of actions followed by percentage of group contributions. Finally, I entered the percentages of the different evaluations as a set: supportive actions, redressed criticism and naked criticism.

In short, the regressions and path analyses predict perceived leadership with a person's: (a) social status, (b) mathematical grade, (c) mathematical status, (d) percentage of group's words, (e) percentage of correct turns, (f) percentage of group's contribution turns, and (g) percentage of supportive turns, percentage of naked criticisms, and percentage of redressed criticisms.

Predicting received supportive evaluations. Correct turns should receive supportive evaluations so I first entered percentage of correct turns. Then I tested for status effects by entering social status and mathematical status together. In short, I predicted percentage of received support with (a) percentage of correct turns and (b) social status and mathematical status.

All results were significant at the .05 level.

Results

As expected, the students found the problem difficult (see table 1). Only 9 or the 20 groups solved it correctly, and every group made at least three mistakes. Of the 3153 total speaker turns, 49 turns were not coded because of poor sound quality. Overall, the evaluations included 54% supportive, 0.3% neutral, 18% redressed criticism, 9% naked criticism, and 16% unresponsive turns (Cohen's kappa = .93, z = 49.5, $p < .001$). Knowledge content included 19% correct contributions, 9% wrong contributions, 17% correct repetitions, 4% wrong repetitions, and 48% null content turns (kappa = .94, z = 60.4, $p < .001$).

Insert table 1 about here

Group level: predicting solution score

Mean mathematical grade, percentage of correct turns, percentage of supportive agreements, and percentage of redressed criticisms positively predicted solution score while percentage of naked criticisms negatively predicted solution score (see table 2). Meanwhile, social status, mathematical status, and total words had positive effects on solution score, but were not significant. Likewise, social status standard deviation, mathematical status standard deviation, leadership concentration and total contributions had negative effects on solution score but were not significant.

Insert table 2 about here

Hierarchical regression with only the significant variables (mathematical grade, percentage of correct turns, and the three evaluations' percentages) showed consistent results with an R^2 of .87, $\underline{p} < .001$ (see appendix E).

Most of the effects of both mathematical grade and likelihood of correct turns were indirect, whereas the evaluations' effects were primarily direct. The indirect effects of mathematical grade operated primarily through mathematical status and percentage of correct turns (see table 3). As expected, mathematical grade predicted both mathematical status (B=.68, $\underline{p} < .01$) and percentage of correct turns (total $\beta = .48$, $\underline{p} < .05$, direct $\beta = .10$). Mathematical grade also correlated with social status ($r = .52$, $\underline{p} < .05$). The indirect effects of percentage of correct turns operated through each evaluation as well. Not surprisingly, percentage of correct turns positively predicted percentage of supportive turns and negatively predicted percentage of naked criticism turns.

Insert table 3 about here

The path analysis showed that total words did not positively predict solution score in part because total words did not positively predict percentage of correct turns (total $\beta = -.22$) or total contributions (total $\beta = -.40$). When using only the significant variables in a path analysis, mathematical grade showed a significant direct effect on percentage of correct turns (see appendix E). Otherwise the results were similar.

Individual level: predicting leadership and received supportive evaluations

The students typically assigned most of the group leadership to one or two people with a small percentage to the remaining members of the group (see table 4). Eight of the twenty groups assigned more than 90% of the leadership to one person.

Insert table 4 about here

Predicting perceived leadership

Social status, percentage of group words, and percentage of naked criticism turns showed both total and direct significant positive effects on perceived leadership while percentage of redressed criticism turns showed both total and direct negative effects on perceived leadership (see table 5). Meanwhile, mathematical grade and mathematical status had positive effects on perceived leadership, but were not significant. Likewise, percentage of correct turns, percentage of group contributions, and percentage of supportive turns had negative effects on leadership, but were not significant. About half of the social status effect was direct, while over 85% of the other significant predictors' total effects were direct. Hierarchical and simultaneous regressions with only the significant variables (social status, percentage of group words, and the two criticism percentages) showed consistent results with an R^2 of .65, $p < .001$ (see appendix F).

Insert table 5 about here

Social status had a large indirect effect on perceived leadership, of which 60% operated indirectly through percentage of group's words' direct effect on leadership and the remaining 40% operated indirectly through percentages of group's words' and of group's contributions' indirect effects on perceived leadership via percentages of naked and redressed criticism turns (see table 6). Social status positively predicted percentage of group words (total β =.41, p <.001, direct β = .30, p <.05) and percentage of the group's contributions (total β = .64, p <.001, direct β = .29, p <.01). Of the remaining 14% indirect effect of percentage of group words' on perceived leadership, 11% occurred through percentage of redressed criticism turns' direct effect on perceived leadership.

Insert table 6 about here

Mathematical grade positively and significantly predicted percentage of correct turns (total β= .53, p <.05, direct β= .30, p < .05), but not percentage of group words (total β=.19). Mathematical status did not positively predict percentage of group words either (total β= -.03).

Social status positively and significantly predicted percentage of redressed criticism turns (total β = .41, p <.01, direct β= .02), but not naked criticism (total β= .02). Meanwhile, mathematical status positively and significantly predicted percentage of naked criticism turns (total β=.32, $p < .05$, direct effect = -.05), but not percentage of redressed criticism turns (total β= .16). Mathematical grade did not significantly predict either criticism (naked: total β =.10; redressed: total β =.21).

In a separate hierarchical regression, social status, but not mathematical status, positively predicted percentage of received supportive evaluations after controlling for percentage correct (see table 7).

Insert table 7 about here

Discussion

Variables that positively predicted successful group solutions did not positively predict perceived leadership. Mathematical grade, percentage of correct turns, percentage of supportive turns, and percentage of redressed criticism turns positively predicted solution score while percentage of naked criticism turns negatively predicted it. In contrast, social status, percentage of group words, and percentage of naked criticism turns positively predicted perceived leadership while percentage of redressed criticism turns negatively predicted it.

At the group level, both mathematical ability and evaluations predicted correct solutions. As expected, mathematical ability (as measured by mathematical grade) predicted correctness at the turn level, and both predicted successful solutions, whereas quantity of interaction and status did not. These results are consistent with St. John's (1996) study showing that student scores on standard mathematical tests predicted complex mathematical thinking but social status did not. Quantity of interaction (words) did not significantly affect the solution score, but quality did, through correctness and evaluations. As expected, polite evaluations (supportive and redressed criticisms) facilitated group work while impolite evaluations (naked criticisms) hindered it. Social status and status variances had the predicted effects, but did not significantly affect the group solution score. In short, both mathematical ability and evaluations influenced collaborative problem solving success, showing the importance of both cognitive and social factors.

At the individual level, status influenced perceived leadership. Social status predicted leadership whereas mathematical ability (grade) did not. Social status also predicted percentage of group words and both predicted leadership, consistent with Dembo & McAuliffe's (1987) study showing that quantity of interaction predicted leadership. As expected, social status also predicted polite redressed criticism (a social strategy), suggesting that social skills underlie social status. Furthermore, mathematical status positively predicted impolite naked criticism, consistent with St. John's (1996) study showing that being chosen as a mathematics partner (mathematical status) correlated with impolite exclusion of others. These results supported the claim that students with higher social status were socially skillful and polite whereas students with higher mathematical status showed their status by being less polite. Furthermore, naked criticisms positively predicted leadership while redressed criticism negatively predicted leadership, suggesting that impolite behavior enhanced one's leadership image. Finally, social status skewed evaluations as it positively predicted received supportive evaluations after controlling for percentage of correct turns.

Ability and evaluations determined solution score at the group level, but status effects predicted perceived leadership at the individual level. Furthermore, the effect of each criticism on solution score was the opposite of their effect on leadership, showing that the cognitive goal of solving a problem can conflict with the social goal of being perceived as a leader.

Limitations & Future research

This study examined relative strangers working together on a difficult problem and did not distinguish among the varying importance of different contributions. As a result, this analysis does not apply to friends who use impoliteness to signal intimacy (e.g. ritualistic insults [Goodwin, 1990]) and whose disrespectful actions toward one another do not threaten their friendship. For easier problems, the importance of evaluations may diminish because group members are more likely to assess an idea in the same way. Future research can include applying these methods to friends working together and to people working on easier problems. In addition, further distinctions in the relative importance of different contributions may delineate particular effects more clearly. Researchers can also examine whether particular evaluations increase the probability of correct ideas, contributions, and justifications.

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Appendix A: Pre-collaborative group work questionnaire

Name ______________________ Period ______

Who are 3 classmates you would most like to hang out with?

____

____

____

Who are 3 classmates you would choose for your group to learn the most math?

____

____

____

Name 3 classmates who are the easiest for you to talk with outside of school work:

____

____

____

Name 3 classmates that could help you the most with a super hard math problem:

____

____

____

Appendix B: Problem, solution, and coding

Problem:

You've won a cruise from New York to London, but you arrive 5 hours late and the ship has left without you. To catch the ship, you rent a helicopter. If the ship travels at 22 miles an hour and the helicopters moves at 90 miles an hour, how long will it take for you to catch the ship?

Goal:

Find time at which the ship and the helicopter are in the same location

Key problem situation understanding:

After 5 hours, both vehicles move simultaneously at their respective speeds

Solution score:

Correct answer:	3 points
Articulated at least one of the above solution methods:	2 points
Articulated the correct goal and problem situation:	1 point
None of the above:	0 points

Solution #1:

Write distance expression for each vehicle and equate them

ship distance	= helicopter distance
ship speed x ship time	= helicopter speed x helicopter time
22 mph x (T + 5 hours)	= 90 mph x T hours
22 x T + 110 - 22 x T	= 90 x T - 22 x T
110	= 68 x T
110 / 68	= 68 x T / 68
1.6176	= T

Solution #2:

Compute current gap between ship and helicopter, distance ship traveled in 5 hours at 22 mph:

5 hours x 22 mph = 110 miles

Compute net closing speed, helicopter speed minus ship speed:

90 mph - 22 mph = 68 mph

Obtain time by dividing current gap by net closing speed.

110 miles / 68 mph = 1.6176 hours

Solution #3:

Iteratively calculate the additional time needed for the helicopter to travel to the ship's new position.

(a) Compute ship movement after 5 hours

(b) Compute helicopter time needed to travel that distance

(c) Compute distance ship travels in that time

Repeat (b) and (c) until the helicopter and the plane are in the same place (within the length of the ship = 20 feet / 5280 (feet/mile)= .0038 miles).

Ship movement	Helicopter movement
22 mph x 5 hours = 110 miles	
	110 miles / 90 mph = 1.22222 hours
22 mph x 1.222 hours = 26.8888 miles	
	26.8888 miles / 90 mph = 0.29876 hours
22 mph x 0.29876 hours = 6.57273 miles	
	6.57273 miles / 90 mph = 0.07303 hours
22 mph x 0.07303 hours = 1.60666 miles	
	1.60666 miles / 90 mph = 0.01785 hours
22 mph x 0.01785 hours = 0.39274 miles	
	0.39274 miles / 90 mph = 0.00436 hours
22 mph x 0.00436 hours = 0.09600 miles	
	0.09600 miles / 90 mph = 0.00106 hours
22 mph x 0.00106 hours = 0.02347 miles	
	0.02347 miles / 90 mph = 0.00026 hours
22 mph x 0.00026 hours = 0.00574 miles	
	0.00574 miles / 90 mph = 0.00006 hours
22 mph x 0.00006 hours = 0.00140 miles	

Time = 1.22222 + .29876 + .07303 + .01785 + .00436 + .00106 + .00026 + .00006 hours

= 1.6176 hours

Appendix C: Coding Speaking Turns

Code each turn in the 2 following areas:

<u>Knowledge content:</u>

Does the speaker articulate mathematical or problem-related information?

- No, code as <u>null content</u>
- Yes,
  - Is this information on the group's log/trace of problem solving?
    - Yes, code as <u>repetition</u>
    - No, code as <u>contribution</u>
      - and write specific information in this group's log
  - Does this information violate mathematical or problem constraints?
    - Yes, code as <u>incorrect</u>
    - No, code as <u>correct</u>

<u>Evaluation</u>:

Does the speaker respond to the previous speaker?

- No, code as <u>unresponsive</u>
- Yes, does the speaker fully agree with the previous speaker?
  - Yes, code as <u>supportive</u>
  - No, does the speaker disagree with the previous speaker?
    - No, code as <u>neutral</u>
    - Yes, does the speaker soften the criticism? (see list below)
      - Yes, code as <u>redressed criticism</u>
      - No, code as <u>naked criticism</u>

Some actions that soften/modify criticism:

hypothetical (if..., let's say ..)

indirect responsibility - passive voice (is multiplied), passive verbs (get, have),

no reference to the past speaker, cite other people

first-person plural pronouns (we, our)

repetition of previous speaker's words

hedge (could, probably)

Appendix D: Hierarchical regression and path analysis on solution score, reduced variable set

Hierarchical regression on solution score using only significant variables from the full hierarchical regression with total effect Betas, direct effect Betas, and variance of solution scores explained.

	Total Effect ß	Direct Effect ß	Variance, R^2
Math Grade	.66 **	.05	.43 **
% Correct turns	.56 **	-.64	.25 **
% Agreement turns	1.19 **	1.19 **	
% Naked criticism	-.66 **	-.66 **	
% Redressed criticism	.55 **	.55 **	.19 *
Total R^2			.87 ***
Total Adjusted R^2			.82

*p < .05, **p < .01, ***p< .001

Path analysis of reduced set of variables influencing solution score (left to right)

	% Correct	% Supportive	% Naked criticism	% Redressed criticism	Solution Score
Math grade	.47 *	.20	-.10	.09	.05
% Correct		.79 ***	-.78 ***	-.45	-.64
% Supportive					1.19 **
% Naked criticism					-.66 **
% Redressed criticism					.55 **

*p < .05, **p < .01, ***p< .001

Appendix E: Hierarchical regression and path analysis on perceived leadership, reduced variable set

	Total Effect ß	Direct Effect ß	Variance, R^2
Social Status	.50 ***	.29 ***	.25 ***
% Group words	.65 ***	.60 ***	.35 ***
% Naked criticism		.24 **	
% Redressed criticism		-.24 **	.05 **
Total R^2			.65 ***
Total Adjusted R^2			.62

**$p < .01$, ***$p < .001$

Path analysis of reduced set of variables influencing perceived leadership (left to right)

	% Group words	% Naked criticism	% Redressed criticism	Solution Score
Social Status	.41 ***	.11	.35 **	.29 ***
% Group words		.37 **	.15	.60 ***
% Naked rejection				.24 **
% Redressed rejection				-.24 **

**$p < .01$, ***$p < .001$

Footnote

[1] Entering different subsets of (social status, variance of social status, mathematical status and variance of mathematical status) into the hierarchical regression did not change the results.

Table 1.
Summary group level statistics (N=20)

Variable	Mean	Std Dev	Minimum	Maximum
Solution Score	1.9	1.3	0	3
Group mean mathematics grade	81	6.8	70	92
Group mathematical status	24	11	2	25
Group social status	24	8.2	4	12
Social status standard deviation	5.5	2.7	0.5	10.4
Math status standard deviation	12.9	8.2	2.6	25.7
Words	1363	1175	371	3885
% Correct	.44	.22	.11	.93
Contributions	43	33	12	123
% Supportive	.59	.14	.39	.86
% Naked Criticism	.09	.05	.02	.19
% Redressed Criticism	.16	.06	.06	.27
Concentration of Perceived Leadership	.71	.25	.29	1.00

Table 2.
Hierarchical and simultaneous regressions predicting solution score with total Betas, direct Betas, and variance of solution scores explained.

	Total Effect ß	Direct Effect ß	Variance R^2
Math grade	.66 **	.03	.43 **
Social status	.30	-.22	
Math status	.09	.43	
Social status standard deviation	-.35	-.03	
Math status standard deviation	-.27	-.31	.12
% of group words	.17	.01	.02
% Correct turns	.72 **	-.59	.27 **
% of group contributions	.29	-.32	.00
% Supportive	1.44 *	1.43 *	
% Naked criticism	-.86 *	-.83 *	
% Redressed criticism	.68 *	.69 *	.10 *
Leadership concentration	-.03	-.03	.00

Note. total R^2 =.94, adjusted R^2 =.83

*$p < .05$, **$p < .01$

Table 3.
Path analysis of variables influencing solution score (standardized beta regression coefficients from left to top)

	Mean Social Status	Mean Math Status	S.D. Social Status	S.D. Math Status	Words	% Correct	Contributions	% Supportive	% Naked criticism	% Redressed criticism	Leadership concentration	Solution Score
Math grade	.52 *	.73 **	.40	.75 **	.53	.10	-.05	.21	-.14	-.12	.54	-.03
Social Status					.37	.25	-.15	-.15	.00	.43	.38	-.22
Math status					-.32	-.14	.82 *	-.05	.19	.39	-.39	.43
S. D. Social Status					.39	.00	-.41	-.07	.22	-.15	.07	-.03
S. D. Math Status					-.19	.51	-.58	.08	.23	-.32	-.13	-.31
Words						-.22	-.29	.20	-.34 *	.01	.22	.01
% Correct							.52 *	.77 **	-.56 *	-.40	.32	-.59
Contributions								.05	-.57 *	-.34	.98	-.32
% Supportive											-.32	1.43 *
% Naked criticism											.99	-.83 *
% Redressed criticism											.15	.69 *
Leadership concentration												-.03

*p < .05, **p < .01, ***p< .001

Table 4.

Summary statistics for individual variables (N=80)

Variable	Mean	Std Dev	Minimum	Maximum
Mathematics grade	81	11	52	99
Mathematical status	5.9	5.7	0	53
Social status	5.8	5.2	0	24
Perceived Leadership	.25	.34	.00	1.00
% of group words	.25	.23	.00	.72
% Correct	.37	.27	.00	1.00
% of group contributions	.30	.22	.00	.77
% Supportive	.51	.27	.00	1.00
% Naked criticism	.08	.07	.00	.25
% Redressed criticism	.14	.11	.00	.50

Table 5.
Hierarchical Regression on leadership

	Total Effect ß	Direct Effect ß	Variance, R^2
Social Status	.50 **	.23 *	.25 **
Math Grade	.18	.11	.02
Math Status	.13	.03	.01
% of Group Words	.64 **	.55 ***	.32 **
% Correct turns	- .11	-.09	.01
% of Group Contribution turns	- .03	.11	.00
% Support turns	- .03	-.03	
% Naked criticism	.24 **	.24 *	
% Redressed criticism	- .27 **	-.27 *	.05 *
Total R^2			.66 ***
Total Adjusted R^2			.61

*p < .05, **p < .01, ***p< .001

Table 6.
Path analysis of variables influencing perceived leadership (standardized beta regression coefficients from left to top)

	Math status	% of group words	% Correct	% of group contributions	% Supportive	% Naked criticism	% Redressed criticism	Perceived Leadership
Social Status	.15	.30 *	.20	.29 ***	.01	-.07	.02	.23 *
Math grade	.68 ***	.08	.30 *	.08	.27	.05	.17	.11
Math status		.13	.16	-.07	-.34 **	-.05	-.15	.03
% of group words			.07	.42 ***	.13	.09	-.26 *	.55 ***
% Correct				.44 ***	.92 ***	-.28	-.19	-.09
% of group contributions					-.21	.64 **	.88 ***	.11
% Support								-.03
% Naked rejection								.24 *
% Redressed rejection								-.27 *

*$p < .05$, **$p < .01$, ***$p < .001$

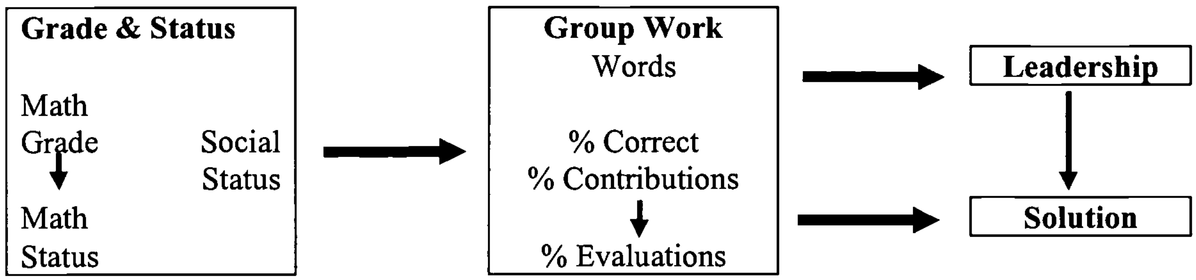
Table 7.
Hierarchical regression on percentage of received supportive evaluations

	Total Effect ß	Direct Effect ß	Variance R^2
% Correct	.70 ***	.66 ***	.50 ***
Mean Social Status	.25 *	.25 *	
Mean Math Status	-.13	-.13	.04 *

*$p < .05$, **$p < .01$, ***$p < .001$

Figures

Figure 1. Model of temporal and causal relationships among variables that affect perceived leadership and group solutions.


Grade & Status
Math
Grade
Math
Status
Social
Status
Group Work
Words
% Correct
% Contributions
% Evaluations
Leadership
Solution

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