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ABSTRACT

In the last few years educational researchers have become increasingly aware of the need to examine interaction among students to understand the impact of cooperative small groups on learning. For this study 26 students in an 11th-grade Algebra II/Trigonometry class were trained to use a didactic cooperative learning technique called scripted cooperation. The study was designed to explore the nature of students' verbal interaction within this cooperative structure, how that interaction changed over time, and its relationship to achievement. Findings from analysis of transcripts of students working in groups, chapter tests, and student characteristics instruments included the fact that none of the 24 categorized interaction sequences or behaviors was significantly related to ability as measured by prior mathematics achievement. Contains 51 references. (MKR)

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SCRIPTED COOPERATION IN HIGH SCHOOL MATHEMATICS: PEER INTERACTION AND ACHIEVEMENT

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For this study students in an upper level high school mathematics class were trained to use a dyadic cooperative learning technique called scripted cooperation. The study was designed to explore the nature of students' verbal interaction within this cooperative structure, how that interaction changed over time, and its relationship to achievement. Analyses were made to determine how, under scripted cooperation, specific verbal interactions were associated with achievement and how certain student characteristics were associated with specific verbal interactions.

INTRODUCTION

Background

Peer interaction. In the last few years educational researchers have become increasingly aware of the need to examine interaction among students to understand the impact of cooperative small groups on learning. In her investigations into the kind of peer interactions that predict high achievement, Webb (1985) found that in general a student's giving and receiving "help" within a group had no effect on the student's achievement. However, the **kind** of help that was given or received did affect achievement. Her studies revealed that giving substantive explanations had a positive effect on the achievement of the explainer, but giving short-answer responses had none. Receiving substantive explanations could have a positive effect on the receiver, but receiving short-answer responses had a negative effect, and receiving no response to a request for help had an even more negative effect on the achievement of the requester. Studies similar to Webb's have produced results consistent with her earlier findings. In a review of such studies, Webb (1989) concluded that a few kinds of verbal interaction were consistently related to achievement: giving content-related explanations (positive correlation), receiving a lower level of help than requested (negative correlation), and off-task discussion (negative correlation).

These studies also lend support to the notion of a continuum of content-related help responses that differ in their effect on achievement according to the amount of explanation or elaboration students give (Webb, 1991). At the high end of the continuum would be detailed explanations, and at the low end would be merely stating an answer to a problem. Studies done so far have categorized explanations using only the high and low ends. Webb (1991) notes that the research to date leaves unanswered an important question about the nature of elaborated explanations that students should be encouraged to give in small groups. If the nature of effective explanations were known, strategies could be suggested to students to help them formulate and communicate their explanations to peers.

Webb (1991) proposes ten instructional strategies, based on observations of expert teachers and tutors, which she says need to be tested empirically to determine their usefulness for students working in small groups.

(1) Activate students' prior knowledge that is relevant to explaining the concept. The "explainer" must assess what the target student already knows and build upon that material.
(2) Use multiple representations to explain a concept (mathematical symbols, numbers, geometric figures, pictures, etc.).
(3) Show how to coordinate and translate among alternative representations so that the target student can see a concept in multiple ways.
(4) Provide detailed justifications of the reasoning used to solve a problem (e.g., discuss the goals involved in deciding the next step in a problem).
(5) Use specific examples to illustrate a general concept.
(6) Become "tuned into" the target students' problem-solving processes to be able to correct their errors and answer their questions immediately (e.g., proceed through their version of the solution before trying to explain it).
(7) Translate unusual or unfamiliar vocabulary into language that the other students are familiar with.
(8) Assess whether students understand how to solve the problem by giving them opportunities to solve problems by themselves, without interruptions.
(9) Respond to all indications of misunderstanding or incomplete understanding (errors, statements of confusion, questions) with elaborated descriptions instead of brief responses or only the correct answer.
(10) Encourage students to freely admit their lack of understanding and freely disagree with others, and to freely control the pace and content (e.g., topics to be discussed) of the teaching activities.
(Webb, 1991, pp. 384-385)

Several studies using small groups (Webb, 1980, 1982a, 1982b) have focused on peer interaction as a mediating variable between group and individual characteristics and achievement. The results of these few studies of peer interaction suggest that interaction may be a key predictor of achievement. Differential participation helps to explain the research findings of aptitude-by-treatment interactions between ability and kind of grouping (Webb, 1982a) and between personality, gender, and grouping (Hall et al., 1988; Webb, 1982b, 1984a). For instance, Webb (1985) found that the range of ability within groups affects interaction: in homogeneous groups there was wider student participation in giving explanations than in heterogeneous groups, where high ability students offered more explanations to low ability students and medium ability students were relatively silent. Cohen (1984) found that students' status within groups affected their interactions and thereby their achievement: high-status students talked and worked together more often than those of low status, and consequently they became even more competent.

Predictors of peer interaction. If interaction is a key predictor of achievement, it is vital to know what predicts interaction. The major predictors of interaction in the groups studied in Webb's latest review (1991) were the nature of questions students asked each other, the characteristics of the individual (ability, personality, gender), and the composition of the group (ability, gender). General requests for help were less effective at eliciting explanations than explicit, direct requests. In some of the studies boys were more likely than girls to make direct requests, thus were more successful at getting help. High-ability students were more likely to give help than medium or low ability students; extroverts were more likely to receive adequate help than introverts. Group ability compositions that seemed to promote participation by most or all of the members were homogeneous medium-ability groups and groups with a moderate range of ability (highs and mediums, or mediums and lows). Homogeneous high-ability groups, homogeneous low-ability groups, and heterogeneous groups with highs, mediums, and lows were all detrimental to at least some students. Groups with equal numbers of boys and girls promoted more explaining than groups with unequal numbers of boys and girls.

Student characteristics. From a practitioner's point of view, student characteristics must generally be thought of as unchangeable and as affecting achievement. What is intriguing about the latest research on peer interactions is the notion that the interaction mediates the effects of student characteristics on achievement. That research links input to process and process to outcome: student characteristics are a major predictor of interaction in a group and that group interaction predicts achievement. Manipulating group composition with respect to ability, gender, and personality can maximize students' achievement by providing optimum conditions for beneficial peer interaction.

Training. Whereas student characteristics cannot be changed, peer interactions can be changed through group composition and training. Training students to be more effective in cooperative learning situations has not received much attention in studies to date. Ethnographic studies by Deering (1989) and Logan (1986) have demonstrated that students' understanding of what they are to do when they are told to be cooperative often differs substantially from what their teachers and the cooperative learning advocates mean. Many students simply do not know how to be cooperative and have persistent difficulties with conflict. Johnson and Johnson (1985) have pressed the need for extensive teacher training (over 90 hours in some cases), and they and others stress various collaborative skills to be emphasized and reinforced in classroom applications of their cooperative learning methods. But the research is just now beginning to show what specific behaviors and verbal interaction are most likely to boost achievement in cooperative learning, and only a few researchers have studied the effects of training students in those behaviors (Hythecker, Dansereau, & Rocklin, 1988; Swing & Peterson, 1982; Webb, 1991).

In her investigation of the effects of student status, Cohen (1984) used an intervention that trained all students to participate and that created special roles (facilitator, checker, reporter) within the cooperative groups and thereby was successful in decreasing the dependence of student achievement on status among peers. This is a clear example of the value of training students in collaborative skills and of structuring the peer interactions in a cooperative learning situation to ensure broader participation.

Structured peer interaction. Some of the most extensive research on structured interaction has been done by Dansereau and his colleagues (1984; Dansereau, et al., 1979; Hythecker, Dansereau, & Rocklin, 1988; O'Donnell & Dansereau, 1992). In an effort to remedy the weaknesses of prior cooperative learning studies, they introduced systematic manipulation of specific learning and interaction strategies within dyadic studying situations in closely controlled laboratory experiments. Unlike other cooperative learning techniques, their "scripted cooperation" used a script to specify the processing activities of the dyad members.

The roles students played and the nature and timing of their activities were specified in the script. Although the scripts varied somewhat according to the learning material used and the expected outcome, a prototypical script was the one used for text processing. First, the text to be learned was broken down into a number of sections; both partners read the first section of text, then put the material aside. One partner then played the role of "recaller" and recalled as much of the information as possible; the other partner played the role of "listener/detector" and listened carefully to detect errors or omissions. Finally, both partners elaborated on the material, using analogies, images, references to previous material, and any other strategies that would help them remember. Then they proceeded to the second section of text, repeating the read-recall-elaborate process but switching roles. They went though the entire text, processing it in this manner and alternating between the two roles.

Such scripts were designed to incorporate findings from cognitive and educational psychology by including such potentially effective activities as oral summarization (Ross & DiVesta, 1976; Yager, Johnson, & Johnson, 1985), metacognitive activities (Baker & Brown, 1984), elaboration (Reder, 1980), cross modeling and imitation of strategies (Bandura, 1971), and the use of multiple passes through material (Dansereau, 1985).

Through their work they concluded that the script, either imposed by the teacher/researcher or generated by the participants, controlled the peer interaction and thus the achievement outcome. Starting with a text-learning script with a strong theoretical basis in cognition and learning strategies, these researchers devised variants that differentially promoted direct acquisition of text material and transfer of study skills from dyadic to individual studying, depending on which processes (cognitive, metacognitive, affective, and social) the scripts influenced. They found that participant-generated scripts were influenced more by the nature of the participants than by the nature of the task. When students lacked necessary learning skills, they chose inappropriate study strategies; student-generated scripts led to much less interaction than did the imposed ones. Their experiments demonstrated that well-conceived, imposed scripts were more effective in producing the outcomes they examined — direct acquisition of information and skills and transfer of study strategies to individual studying. According to these researchers (Dansereau, 1987; McDonald et al., 1985), the results of their carefully controlled laboratory experiments are potent and consistent enough to warrant the use of dyadic cooperative studying techniques in school environments.

Summary. In summary, the key feature in cooperative learning is peer interaction. Although interaction has frequently been studied over the years in relation to affective outcomes, its effect on achievement outcomes has received comparatively little attention (Newmann & Thompson, 1987). Those studies that have been done have focused mostly on content-related helping behavior, ignoring many other kinds of verbal interaction that could have important effects on student learning, such as peer regulation, feedback, support, and encouragement (Johnson & Johnson, 1985). Although giving elaborated explanations has been shown to significantly relate to mathematics learning in peer-directed small groups, important questions remain about the nature of elaborated explanations that students should be encouraged to give and about ways to promote effective explaining in small groups (Webb, 1991). Almost no attention has been given to the nature of peer interactions and their effects on achievement over time (O'Donnell & Dansereau, 1992). In one of two studies on group interaction over time reported by Webb (1985), researchers Webb and Cullian (1983) found that students' behavior was fairly stable over time. In the second study Webb (1984b) found that student behavior was unstable over time, although the relationships between interactions and achievement were similar over time. Dansereau and others have demonstrated the potential of using scripts to structure peer interaction to selectively activate a variety of cognitive and metacognitive activities (O'Donnell & Dansereau, 1992). Given the power of peer interactions to mediate the effects of student characteristics on achievement, any knowledge that can be gained in this area has potential application to the design of cooperative learning methods, to the training of teachers in their use, and to the training of students in cooperative learning skills.

What is missing at this point in the literature is the long-term application to a school environment of the findings from the two areas of research developed by Webb and Dansereau regarding the kinds of interactions that predict high achievement. This application along with the systematic observation of the resultant peer interaction are needed to verify their hypotheses regarding relationships among peer interaction, learning outcomes, and student and group characteristics. The research to date, both that done in laboratories and in classrooms, has generally involved only brief periods of training and use of cooperative techniques. Consequently, little is known about the nature of specific peer interaction over time or about the effects of such interaction on achievement over time. Additionally, there is a dearth of research on the application of cooperative learning at the upper high school level (grades 10-12) and especially in mathematics courses at that level (Newman & Thompson, 1987).

Present Study

This study is part of a research program (see Berg, 1992) that attempted to extend the work of Webb and Dansereau in the direction described above and to contribute to an area of the literature on cooperative learning where studies are few (mathematics in grades 10-12). Dansereau's work was used to devise a dyadic studying technique designed to engage students in interactions that theory and research have shown to be beneficial. The prototypical text-learning script from the literature on scripted cooperation was adapted to the needs and restrictions of an Algebra II/Trigonometry class for 11th graders. This newly-devised paired-learning script was used as the primary instructional technique for 8 weeks of instruction in an otherwise conventional class of 26 students.

Achievement was monitored before the implementation of scripted cooperation, during its use, and after the return of the class to a more conventional instructional mode. Peer interactions were tape-recorded numerous times over the course of the 8 weeks of instruction. Tapes were transcribed and analyzed, along with field notes and student questionnaires, using qualitative methodology, to help delineate the nature of students' verbal interaction under scripted cooperation and to assess its change over time. Several categories of behavior were used in subsequent quantitative analyses to answer the following research questions.

Research Question 1. Under scripted cooperation, how are specific verbal interactions (for instance, giving and receiving explanations or confirmatory feedback and encouragement) associated with achievement?

Research Question 2. Under scripted cooperation, how are certain student characteristics (specifically, prior mathematics achievement, learning preference, study skills, and math anxiety) associated with specific verbal interactions?

METHOD

Participants

Participants for this study were 26 11th grade students enrolled in an Algebra II/Trigonometry course at a small, ethnically diverse laboratory school associated with a large university. The class was taught using a commercially available textbook and, except during the 8-week experimental period, a conventional class structure and teaching routine. The range of students' stanine scores on the Stanford Achievement Test mathematics subtest was from 5 to 9, with a mean of 7.54.

Instruments

Achievement measures. Algebra achievement was measured using the chapter tests provided in the textbook teacher materials. Tests were scored on a 100-point scale, using a focused holistic scoring point scale that allowed partial credit for partial solutions (Randall, Lester, & O'Daffer, 1987)

Student characteristic measures. Instruments used to measure student characteristics included three self-rating scales, the Learning And Study Skills Inventory (LASSI), the Learning Preference Scale for Students (LPSS), and the Mathematics Anxiety Rating Scale-A (MARS-A), in addition to the Grade-10 Stanford Achievement Test (SAT) mathematics subtest.

Approximately 4 weeks before the study began, students took the high school version of the LASSI (Weinstein & Palmer, 1988), a self-report measure of students' use of learning and study strategies. There are 10 scales on the LASSI (e.g., Motivation, Information Processing, and Selecting Main Ideas); no total score is computed. Coefficients α for the scales range from a low of .68 to a high of .86, and test-retest correlation coefficients range from a low of .72 to a high of .85 (Weinstein, Schulte, & Palmer, 1987).

Students took the LPSS (Owens & Straton, 1980) approximately 3 weeks before the study began and again right after the last experimental phase ended. The LPSS yields three scale scores relating students' preferences for cooperative, competitive, and individualized learning modes as three independent preference dimensions. Cronbach α coefficients for the three scales for upper high school students vary from .68 to .73, indicating substantial homogeneity for each of the scales. However, test-retest correlation coefficients indicate only modest stability; they vary from .54 to .67.

Three weeks before the study began, students were administered the MARS-A, a 98-item self-rating scale that measures math anxiety (Suinn, 1988). Reliability statistics indicate that the measure is highly stable and internally consistent. The reliability coefficients from the Spearman-Brown and Guttman Split-half analyses were reported to be .89 and .90, respectively; the reported Coefficient α was .96 (Suinn, 1979).

Students' 10th-grade Stanford Achievement Test (SAT) mathematics subtest scores were used in this study as a measure of students' prior mathematics achievement (ability). The test had been administered approximately one year prior to the group's treatment.

Post-experiment questionnaire. The day after the last experimental phase ended, students in the study filled out a 25-item questionnaire that used both rating scale and free-response formats.

Materials and Procedures

Textbook materials. For this study students used their regular textbook, *HBJ Algebra 2 with Trigonometry* (Coxford & Payne, 1983), a standard textbook for college-track high school mathematics courses. The textbook format was conventional, similar to other textbooks on the market, and included the following: daily lessons consisting of an introduction then one or more elaborations of a concept, each followed by an example problem with correct solution, then a set of classroom exercises, and finally written exercises for homework assignments. Topics in the chapters used for this study included radical equations, quadratic functions, and imaginary numbers.

Student assignment to dyads. Students were assigned to dyads on the basis of personal preference and teacher discretion. Although some student preferences crossed gender lines, only same-sex dyads were formed to control for gender effects. On days when absences created an odd number of students, one triad was formed and the third member given a scripted role of observer.

Script development and use. During the experimental period, classroom learning sessions were structured by having students use a dyadic study script that prescribed certain activities and roles for the studying partners. The activities and roles specified by the script were based on empirical data from research with explicit learning scripts and on assumptions about learning strategies regarding rehearsal, elaboration, and metacognition. For example, to maximize interactions that involve giving and receiving substantive explanations, behaviors which have been found by Webb (1982b) to correlate positively with math achievement, students were required to study the textbook examples of the algorithms being learned, then to take turns explaining them in detail, inserting the necessary intermediate steps to make their explanations clear to themselves and to their partners. (This role was labeled Explainer.) The receiver of the explanation (labeled Checker 1) was required to detect any errors and omissions in the explanation and to use questions to check the Explainer's understanding as well as to clear up any misunderstandings. This role was designed to engage the Checkers in active listening, which has been found to relate to achievement more than passive listening (Spurlin, Dansereau, Larson, & Brooks, 1984) and is a metacognitive activity shown to be effective for the initial acquisition of information (Larson, et al., 1984).

Right after the explanation of the first text example in their assignment, students used a worksheet provided by the teacher to perform two follow-up tasks to that example. The partner who first acted as Checker 1 used the worksheet to perform a Think-Aloud task, wherein the student solved a problem much like the text example while verbalizing all thinking about the problem. (The Solver role.) The previous Explainer's responsibilities during this phase were to continually check for accuracy and to demand constant verbalization. (The Checker 2 role.) As much as possible, Checker 2 was to let the Solver work through errors to self correction. If corrections were needed, however, they were to be done by using questions and prompts, not by just giving right answers. Whimbey and Lochhead (1982) as well as others have recommended that thinking aloud be used as a routine classroom exercise to teach problem-solving skills. Webb (1991) included in her list of suggested strategies that students might use to make their explanations to peers more effective (see page 2) that explainers assess others' understanding of how to solve a problem by giving them opportunities to solve problems by themselves, without interruptions.

The second follow-up task was called the Summary Question and was to be done by both partners working together. Whenever possible, the Summary Questions specified cooperative elaboration activities that required the use of the mathematical processes of reversibility, generalization, and flexibility, as described by Krutetskii (1976/1968) and which appear to further students' understandings of mathematical concepts. All work for the two follow-up tasks was recorded on the worksheet, and when the students finished the two tasks they switched Explainer and Checker 1 roles to do the second text example in their class assignment. The second example was also followed by two worksheet tasks that students then performed in the switched Solver and Checker 2 roles.

Students were required to switch roles across examples to provide both with the benefits of increased arousal produced by having to verbalize what they study (Hythecker, Dansereau, & Rocklin, 1988). Switching roles also provided both with the opportunity to observe the activities of another, providing for cross modeling and a chance to imitate successful strategies (Bandura, 1971). Figure 1 summarizes the four different roles and three different phases of the scripted learning experience.

The script was also a device to get students to engage mathematical text material to a much greater extent than they do under conventional teacher-dominated classroom structures, where the teacher usually presents all new concepts and operations to the whole class and the students' only required contact with the mathematics text material is with the assigned problem sets they do for homework. Use of the script required students to not only read mathematical procedures and reasoning but also to verbalize and communicate mathematical thinking using mathematical language and terminology. This allowed them to use a wider range of language genres than is usually required in a conventional math classroom (Marks & Mousley, 1990). This learning to read mathematical text material as well as some of the skills described previously might be expected to transfer to tasks beyond the experimental period, based on some of the scripted cooperation research reported by O'Donnell and Dansereau (1992).

The script was designed for use with a regular mathematics textbook in a program of instruction that fit into conventional school schedules (daily 45-minute class periods) and had typical requirements in terms of teachers, lesson preparations, subject-matter coverage, and classroom facilities. Specifically, the script was used by pairs of students during a period of approximately 20 minutes, following a teacher-led introduction to the lesson to be studied. Students had daily homework assignments that were accomplished outside of class. Questions on the previous day's homework assignment were generally handled during the beginning, teacher-led portion of the class period.

Figure 1

Roles and Phases of the Paired-Learning Script

	PARTNER X	PARTNER Y
Phase 1	EXPLAINER Explains first textbook example.	CHECKER 1 Monitors explanation.
Phase 2	CHECKER 2 Monitors solution of problem.	SOLVER Works first Think-Aloud problem on the worksheet.
Phase 3	BOTH partners work together on the first set of Summary Questions on the worksheet, then SWITCH ROLES.	
Repeat Phase 1	CHECKER 1 Monitors explanation.	EXPLAINER Explains second textbook example.
Repeat Phase 2	SOLVER Works second Think-Aloud problem on the worksheet.	CHECKER 2 Monitors solution of problem.
Repeat Phase 3	BOTH partners work together on the second set of Summary Questions on the worksheet.	

Training phase. The teaching of collaborative skills is a necessary part of implementing cooperative learning groups in a classroom (McGlinn, 1991), and the training used in this study took advantage of the suggestions of the practitioners as well as the findings of the researchers in this field (Johnson, Johnson, & Holubec, 1986; Palincsar & Brown, 1984). Students were initially trained in the use of the cooperative studying script over six class periods. Training included a rationale for the various activities required by the script; explicit instructions on the performance of the roles described in the script; live and videotaped demonstrations of the script in use; mediated practice of the individual activities and skills; monitored practice (using audio tape recorders and two observers) of the entire script in dyads, with feedback to the pairs; and a debriefing session to get student feedback and to solve unforeseen problems. Informal training continued into the first experimental phase.

The formal training and subsequent experimental treatment phases occurred over an 8-week period at the beginning of the second semester of the regular school year.

Experimental phases. The experimental treatment period comprised two phases, the first 17 days long and the second 13 days long, each covering one chapter of the text (Chapter 8: Radicals/Quadratic Functions and Chapter 9: Complex Numbers/Quadratic Equations). During each phase, three to six student dyads were tape-recorded each day for three or four days at the beginning and then again near the end of the phase. Students were tested individually on the material, using a short quiz near the middle and a comprehensive chapter test at the end of each phase. Provisions were made for each dyad to be recorded on at least three occasions spread over the 30-day experimental treatment period. In actuality, recordings were done more frequently than this in part to reduce the novelty of the recording situation and capture typical student discourse on tape and in part to compensate for the exigencies that always accompany research done in the field.

Data Analysis

Tape recordings of the students studying in their dyads were transcribed and analyzed along with field notes, questionnaires, and other data according to general qualitative research methods described by Bogdan and Biklan (1982) and further elaborated by Taylor and Bogdan (1984). From the issues and patterns that emerged from the data, several analytic questions were developed regarding students' fidelity to the script, focus on the task, use of mathematical terminology, variation in cooperative behavior, kinds of feedback given to one another's help requests, and kinds of explanations used. These served as the overall coding scheme for all data. Subsequently, related sets of coding categories were developed to help interpret the transcripts in relation to each analytic question. These coding schemes were used to describe and quantify data in order to determine the nature of students' verbal interaction and its change over time and to determine relationships among specific verbal interactions, certain student characteristics, and algebra achievement.

Selection of transcripts for analysis. Because of absences, tapes for only 11 of the 13 dyads were available for transcription to represent the beginning, middle, and end of the experimental period. Tapes for all 11 dyads made in the middle of the experimental period (on days 10, 11, or 13) were selected for the full analysis. These tapes were made late enough in the trial that students were well trained in the use of the script, but early enough that they had not yet had time to substantially customize it. Additionally, four dyads were selected for the examination of change in student interactions over time, two female dyads and two male dyads. In two dyads students had the same math grades the previous semester, one As, the other Cs. In two dyads the partners' previous semester grades differed.

Verbal interaction variables. The literature on small group interaction (Webb, 1991), informed the development of categories for this study but could not be directly applied because of the imposition of the script on students' natural interactions. For instance, all students gave explanations; they were a required part of the script. Thus categories for this study were designed to tap into behaviors that could be expected to affect achievement and where there was variance.

A three-part scoring scheme was devised to describe each student's fidelity to the script. Lines of transcripts of the audio recordings were coded as on or off task to assess students' focus on the assigned material. Uses of mathematical terminology, old and new, were counted.

To assess degree of cooperation, all requests for confirmation and checks for understanding (which were usually not distinguishable) were examined and feedback to them coded as agreement, disagreement, encouragement, or criticism. Unsolicited feedback in these categories was also coded and counted, as were occurrences of control changes and joint and guided productions.

Feedback to direct and indirect requests for help (errors, statements of confusion, questions) was coded as follows: request ignored, request acknowledged but partner showed signs of hesitation or confusion, request responded to with a leading or probing question, request responded to with an answer or correction only, and request responded to with an elaborated answer (explanation).

Finally, for each student a count was made of the number and type of explanations given as feedback to partner help requests. (The formal explanations given by students playing the roles of Explainer or Solver were not the focus of this analysis, since those explanations were constrained by the textbook presentations and were prompted by the script.)

Correlations between verbal interactions and algebra achievement. Students were divided into subgroups of low, medium, and high achievers on the basis of their Chapter 8 test scores. The frequency data and fieldnotes on specific interactions were grouped by student achievement level and examined for patterns and associations. To help validate observed patterns and discover other possible relationships between students' verbal interaction and achievement, a statistical technique borrowed from the literature on small-group interaction and learning (Webb, 1991) was applied to the data. This technique involved the calculation of partial correlations that controlled for ability between several interaction variables and achievement (the dependent variable). In this study students' 10th-grade Stanford Achievement Test mathematics subtest scores were used as the measure of ability (prior mathematics achievement). For the dependent variable, the Chapter 8 test scores were used as a measure of algebra achievement.

To carry out the analysis, several student interaction categories in this study were grouped together to correspond to observation categories examined in previous research (Webb, 1982b, 1991). They included off-task discussion, giving explanations, receiving explanations, and receiving no explanations (divided into subcategories of receiving feedback at a lower level of elaboration than was requested or indicated). Other interaction variables included in the analysis were fidelity to the scripted roles, vocabulary use, joint productions, requests for confirmation or acknowledgement of understanding, and giving and receiving various kinds of feedback to such requests.

A rigorous statistical treatment of this data would have entailed transformations for some of these variables to achieve homoscedasticity. However, given the small frequencies of some variables and the small sample size (N = 22), such a treatment did not seem warranted for this exploratory study. Also, it has been observed that even though there are good theoretical reasons for transformation, in practice the advantages may be slight (Tabachnick & Fidell, 1983). The effect of hetereoscedasticity, since this analysis was based on correlations, was to underestimate the extent of relationship between variables (Tabachnick & Fidell, 1983). This was deemed acceptable for this exploratory analysis.

To explore possible associations between specific verbal interactions and algebra achievement, correlations were calculated between students' Chapter 8 test scores and the original measures of the various interaction variables. Both zero-order (Pearson product-moment) correlations and partial correlations (controlling for prior mathematics achievement) were calculated using standard procedures from CSS: STATISTICA (StatSoft, 1991).

As in the studies from which this technique was borrowed, partial correlations were included to help show whether the relationships between the interaction variables and algebra achievement were due to the effects of interaction or to the prior mathematics achievement of the student. Each partial correlation is the correlation between that particular interaction variable adjusted by prior math achievement (both independent variables in a multiple regression analysis) and algebra achievement (the dependent variable in the analysis), also adjusted by prior math achievement. Thus, each partial correlation represents the unique contribution of that particular interaction to the prediction of algebra achievement (StatSoft, 1991). A significant partial correlation does not confirm that a specific verbal interaction influences algebra achievement. A correlation could be interpreted to mean that students who engage in that kind of interaction already know the algebra material or are the high (or low) achieving students to begin with. By partialing out the effect of prior mathematics achievement, however, a significant partial correlation helps disconfirm this latter interpretation, thus favoring the former, that interaction influences achievement. Comparisons were made between the correlations calculated for this analysis and the correlations for comparable interaction variables and achievement obtained by others in previous research.

Correlations between student characteristics and verbal interactions. The student characteristics under study were prior mathematics achievement, learning preference, study skills, and math anxiety. Results of each student characteristic measure were examined, and correlations were calculated between students' scores and the verbal interaction variables defined in the previous analysis. As part of the overall examination of the data, Pearson product-moment correlation coefficients were also calculated between the characteristic measures themselves and between the characteristic measures and achievement as measured by the Chapter 8 test. Results were compared to relevant findings from previous research.

RESULTS

Nature of Verbal Interaction and Change Over Time

Fidelity to the script. Analysis of the transcripts showed that over half of the 22 students fully played their roles as described in the script, 6 of them played three of the four roles as prescribed, and 4 of them played only two of the scripted roles with fidelity. In all 11 dyads both students were actively involved with the text and worksheet material, even though they did not always restrict their involvement to that called for by the script. The most common departure from the script was with the Checker 2 role, and that was overplayed rather than underplayed in each case. In a couple of dyads the less able partner (as measured by SAT-math scores and/or first-quarter course grades) often deferred to the more able one, in some cases inviting the more able partner to overplay the checker roles. In these same dyads the more able partner would sometimes ensure the success of his less able partner by volunteering to do the harder of any two activities, leaving the easier one for his partner. In two of the dyads one of the partners did both explanations; it was implied by their dialogue that that partner was the one who understood better what was being done in the example.

Focus on the task. Students were generally focused on the task. Their scripted interactions averaged about 230 lines of transcript of which an average 216 lines (94%) were focused on the task and an average of 14 lines (6%) included off-task behavior. Individual students ranged from highs of 100% on-task verbal interaction to a low of 79% on-task interaction. Most off-task interactions were of very short duration and did not seriously interrupt the students' work. Except for the dyad with the low rate of 79%, all ten other dyads were focused on the task for at least 89% of the lines of their transcripts.

Mathematical terminology. The number of mathematical terms used by students varied widely. Usage ranged from a low of about 4 terms per page for one student to a high of about 15 for two other students and averaged almost 11 math terms per student per page of discourse. The average total number of all mathematical terms used by an individual student during his or her dyad time was over 100 and about 13 of those mathematical terms were new terms. New term usage varied from a low of 3% of all mathematical terms used for one student to a high of 23% for another. There were no apparent patterns to this differential use.

Cooperative behavior. Indicators from the transcripts, data from the post-experiment questionnaire, and scores from the LPSS were used to help determine how dyads varied in their degree of cooperative behavior. Transcripts were coded for all requests for confirmation and checks for understanding, which were often one and the same, along with their responses. This feedback fell into four categories: agreement, which included statements of understanding; disagreement, which took the form of both statements and questions; encouragement; and criticism. These four kinds of feedback were also proffered by students to their partners without any direct verbal solicitation and were coded by category as unsolicited feedback.

Analysis revealed that direct questions rarely went unanswered (and those that did could have been answered nonverbally with head shakes). There was almost no criticism of partners. The 3 negative remarks among the over 500 remarks categorized were all made by the same individual, who was, in his defense, attentive to his partner, responding verbally to 11 of 12 partner requests for confirmation/understanding. A large proportion of his responses were disagreements (6 of 11), but these may have less to do with cooperative behaviors than with this student's misunderstanding of the mathematical material being discussed. Finally, students seemed to be very attentive to one another, as indicated by the numerous unsolicited responses indicating agreement and/or understanding. These averaged almost 13 per student. The majority were one-word agreements like "okay" uttered during their partner's performances of the Explainer or Solver roles. Such utterances could also be interpreted as encouragements to continue, although there were also more obvious encouragements and praise such as "It's not hard, you can do it" and "Just keep on talking . . . you're doing it right." Some dyads' relatively low total of requests and responses must be considered along with the results of the next analysis, which looked at another kind of interaction that usually occurred when neither partner was playing a controlling role.

"Joint" and "guided productions" and attempts to usurp controlling roles were analyzed as part of the examination of cooperative behavior. These categories were usually applied to a series of interactions surrounding the solution of a specific problem or performance of a task specified by the script and follow-up worksheets. When students followed the script, formal control of the interaction alternated among three situations: (1) the Explainer in control, then (2) the Solver in control, and then (3) neither formally given control for the Summary Questions. In this analysis, usurpation was considered cooperative behavior when it happened with the partner's consent, as when the student who was supposed to be in control was too confused to effectively perform the role and implicitly or explicitly relinquished control. This sometimes resulted in a complete exchange of roles. Other times it resulted in a "guided production"—the Checker would take control of the executive functions of the problem-solving process and guide the partner through the mechanics of the solution. Usurpation of control, or attempts at it, without the partner's explicit consent were usually considered uncooperative. This seemed to occur most often when the Checker for the Think-Aloud Problem Solver interjected himself too much into the problem-solving process. "Joint productions" occurred most often during the Summary Questions and when both partners had an equal grasp of the material, which was not necessarily a full understanding of it. In joint productions students seemed to take turns vocalizing the solution steps of the problem, often finishing one another's sentences, talking simultaneously, or echoing one another. On a few occasions the Explainer or Solver got bogged down and asked for help, prompting the Checker to step in. But rather than usurping total control, the Checker often just shared control in what became a joint production. Figure 2 contains an example of a joint production by students "s" and "t." Dashes represent undecipherable utterances, and the quoted lines were read word-for-word from the worksheet Summary Questions. Unlike many joint productions, there is no simultaneous speech in this one.

Figure 2

Example of a Joint Production

s. "Show why the axis of symmetry is x equals negative 3 for this parabola y equals x squared plus 6 x by setting y equal zero, by setting y equals zero and following the" direction, what is that?
t. *Derivation.*
s. "the derivation in Example 1."
t. *Oh. See it's saying y equals 0, right?*
s. Yeah.
t. *So x squared plus 6 x equals zero.*
s. Yeah.
t. *You factor for x.*
s. Yeah.
t. *x plus 6. equals zero. So x equals zero, by*
s. ---
t. --- *doing this, okay?*
s. Okay.
t. *How 'bout --- gonna work backwards, right?*
s. Yeah, you know that x is negative 3.
t. *So that'd be negative 6, right? And this'd be y, wait, that'd be 2, right? Cause the negative 3.*
s. Yeah, okay. That's it.
t. *Right?*
s. Okay.
t. *Okay.*
s. You gotta minus the 6. x plus 6 equals zero, yeah, so put, can put the six on the other side. Minus 6 on the other side.
t. *Oh, --- ---*
s. One more step
t. *x equals 6.*
s. Negative 6, cause you minus 6 from both sides, right?
t. *Okay.*
s. Okay. I have to explain now. This is example 2. Okay. You have to first

To summarize the results of the transcript analyses for variations in cooperative behavior, there were variations in the kinds of cooperative roles that emerged and there were differences in the degree of cooperation between students in the dyads. The kinds of cooperative roles seemed to be defined by the relative equality of the partners in terms of their understanding of the material, with the tutor-tutee relationships on the one extreme, moderate understanding by both partners in the middle, and a firm grasp of the material by both partners at the other extreme. Most students seemed to accommodate their partners' strengths and weaknesses, playing model, guide, monitor, equal, or tutee, as required. The variation in the degree of cooperative behavior was an indication of how well individual partners accommodated themselves to the roles that their situations indicated. The students who usurped control without their partners' consent either misjudged or were unwilling to accept roles as monitors of or equals with their partners in those particular tasks. The students who usurped control with the partners' consent were being very cooperative, taking cues to help a partner who was in trouble or who preferred playing the role of tutee with an accommodating tutor.

Overall, LPSS scores and questionnaire responses supported the impression that students were very cooperative. Given their high pre-experiment scores on the cooperative subscale, this did not seem to be a function of the paired-study program. The program, however, was a positive enough experience that post-experiment scores on the cooperative subscale remained high and even increased a bit, though not significantly. Means on the individualized and competitive scales remained lower. Students had a marked preference for cooperative situations that was evident in their LPSS scores and in their taped interactions.

Feedback to help requests. According to the work on task-related verbal interaction and mathematics learning in small groups summarized by Webb (1991), some of the most instructionally significant exchanges were those begun by one student's request for help. This study looked at what happened after direct and indirect requests for help that took the form of questions about the problem at hand ("Where does the zero come from?"), direct requests for explanations or other assistance ("I need an explanation, please." or "How do you do that?"), statements of confusion ("I guess I don't understand what they mean by congruent."), statements of disagreement ("No they won't." or "Wait."), and errors. One of the ten strategies Webb (1991) suggested might be useful for students working in small groups addresses statements such as these. Her suggestion is to "respond to all indications of misunderstanding or incomplete understanding (errors, statements of confusion, questions) with elaborated descriptions instead of brief responses or only the correct answer" (p. 385).

Since the script called for students to give explanations to one another for at least two thirds of their tasks, these students received elaborated descriptions whether they asked for them or not. Most of the explanations in the transcripts were not prompted by direct or indirect requests for help. Nonetheless, within this context of rather constant explanation, there were requests for help, questions inviting further explication of the topic, and errors. The direct and indirect help requests were coded, and the responses to them were categorized as follows: request ignored, request acknowledged but partner showed signs of hesitation or confusion, request responded to with a leading or probing question, request responded to with an answer (or correction) only, request responded to with an elaborated answer (explanation).

Tallies of these help request/response exchanges show no direct requests for help or statements of disagreement were ignored. In both cases they were responded to over 50% of the time with elaborated answers (explanations). Over 80% of the time they prompted some kind of answer, either an unelaborated one or an explanatory response. Most of the rest of the time the requests and disagreements were met with mutual confusion or hesitation. Almost 50% of the statements of confusion were responded to with explanations. A quarter of them prompted acknowledgment coupled with some sign of mutual confusion from their partners. These mutual confusions often accompanied joint productions, which occurred most often during the Summary Questions, where the script made no controlling/explaining role assignmer, ıd the questions were usually extensions of the topic rather than direct applications of ıt.

About 20% of the errors that students made were corrected by their partners providing just the right answer with no elaboration. Fewer than 10% of errors prompted elaborated answers. At first blush, this seems to be disturbingly at odds with Webb's (1991) suggestion. But, interestingly, given the instructions to students to not give answers when playing the role of Checker but to use questions instead, students responded with leading questions to about 30% of the errors. At least as many errors as were questioned were ignored, however, about 35%. In some cases they actually were ignored because they were minor, slips of the tongue, misuses of new terminology, or misstatements that did not affect the progress of the problem solution or explanation. In several cases, however, the errors were not purposely ignored but went undetected by either partner and were major errors that resulted in incorrect answers to problems and misconceptions. In at least two of these cases the teacher was called upon for help and pointed out students' mistakes. In other cases, students checked the chalkboard for the correct answers, and they caught their own errors. Not all misconceptions and errors were detected and corrected, however.

Explanation strategies. The focus of this analysis was not the formal explanations given by students playing the roles of Explainer or Solver, but, rather, the smaller, more spontaneous units of explanation given in response to the direct and indirect help requests previously coded. These often occurred within the larger, more formal explanations called for by the script.

By using some of the 10 explanation strategies suggested by Webb (1991) as a starting point and reexamining the transcripts with particular attention to student explanations, the following set of categories was developed to describe the kinds of strategies used by students in this study when explaining algebra concepts and problems. It was hoped that a set of mutually exclusive categories could be devised; it was assumed that students would frequently use more than one strategy in a given explanation. It was accepted that no set of categories would be exhaustive, but this one provided enough classifications to reasonably accommodate most of the transcript data. Categories are listed below with the one-letter labels used for them when coding the transcripts.

- **X** — Creating, selecting, or referring to (other) specific examples to illustrate a general idea or procedure.
- **V** — Viewing a problem from the other person's perspective, as indicated by perception checks (e.g., using the partner's statements and phrasing when explaining) and by monitoring actions (e.g., catching errors and giving leading questions, suggestions, or prompts).
- **P** — Drawing or sketching a picture (or graph) or referring to an illustration already provided.
- **T** — Translating, elaborating on, or defining terminology or vocabulary.
- **R** — Selectively reading from or referring to relevant text passages, usually word for word, using them as reference or authority.
- **C** — Checking that the partner understands, encouraging the partner to admit lack of understanding, showing readiness to explain further, or having the partner restate a solution in his or her own words.
- **G** — Explicitly stating or implying by its execution a general rule, idea, or procedure or carrying out a standard calculation to justify steps in the solution of a problem.

The examples in the textbook that students were to explain as part of their learning script were many times direct uses by the textbook authors of the first (X) strategy, selecting specific examples to illustrate general ideas or procedures. Students then found themselves put into a specific example, and they had to understand and explain to each other the steps and logic of the specific problem and to connect it to the broader generalization. They usually justified the steps and logic by using one or more of the other strategies described here: P, T, R, or, more often, G. During the Think Aloud problems, when they referred back to the text problems after which the Think Alouds were modeled, they were using the X strategy themselves. The Summary Questions also provided opportunities for them to create specific examples (X) to test their answers to questions that often asked for generalizations. Strategies V and C were often used along with others. The scripted role of Checker 2 to the partner's Solver was a formalization of the V strategy, but that interaction was not usually coded as such, since it did not occur in response to help requests. Students sometimes used it outside that scripted portion of their interaction, though.

The frequency of solicited explanations (the formal explanations prompted by the script are not included here) was fairly low, averaging only about 3 explanations per student. There was a great deal of variance in the distribution, as well, and no obvious patterns with respect to students' prior grades or achievement.

The most popular strategy resorted to by far was that of stating or executing a general rule or procedure, step by step, with the specific problem at hand (G). Translating and interpreting terminology (T) was a distant second-most-used strategy, and nearly as frequent were quoting or referring to the textbook (R) and creating or referring to a specific example to illustrate a general idea or procedure (X). By the nature of the coding process and because it is not a content-related explanation strategy, the checking for understanding strategy (C) always appeared in conjunction with other strategies in this analysis. In fact, it was used extensively by some dyads during the formal explanations not categorized here; its use was captured in the examination of responses to explicit requests for confirmation and checks on partner's understanding done as part of a prior analysis.

Changes over time. For the four representative dyads selected for analysis over time, comparisons were made of discourse behavior over three occasions spanning the beginning, middle, and end of the treatment period. Coding schemes that yielded the most useful information in previous analyses were used on these transcripts: ratings for fidelity to the script; coding for off-task interaction; categories of cooperative behavior, including requests for confirmation/understanding and control of interactions; and the kind of feedback given after direct and indirect requests for help.

In addition to the selected transcript analyses, all students' answers to the post-experiment questionnaire were tallied. When asked about whether or not they had changed the script in any way, students indicated on average they made "some" changes. When asked to describe their changes, 19 of the 26 students in the group described some change. Several reported changes in their initial preparation for playing the roles; some dyads said they worked the Think-Aloud problems together. In some dyads the person who understood the topic better started the explanations and sometimes did them both. One dyad would skip the explanations and go right to the worksheet; another did the worksheet first, then went back and did the explanations if there was time. Others reported they would both help out in explaining everything, relaxing the roles, as one student put it, "melding the two into one." Others reported not being thorough in explanations, going on even when they were confused, or changing the assignment of activities to accommodate a partner who needed more practice.

In general, the changes in interactions over time included an adjustment to the artificiality of playing roles and of being taped, a softening of the distinction between the roles for some dyads, more frequent off-task interaction for those who tended to it initially, and perhaps more strain in dyads where the initial cooperation was least.

Verbal Interactions, Student Characteristics, and Achievement

The analyses to determine the nature of students' verbal interaction under scripted cooperation yielded a number of interaction variables. These were used to formulate two general research questions about the relationship of verbal interactions with achievement and with student characteristics.

RESEARCH QUESTION 1

Under scripted cooperation, how are specific verbal interactions (for instance, giving and receiving explanations or confirmatory feedback and encouragement) associated with achievement?

Patterns by high, medium, and low achievement. Students were divided into subgroups of low, medium, and high algebra achievers on the basis of their Chapter 8 test scores, resulting in 11 "highs," 5 "mediums," and 6 "lows." Selected interactions were grouped by student achievement level and examined for patterns and associations.

From the analysis of fidelity to the script there emerged no clear patterns. In all three cases about half of the group showed 100% fidelity to the roles, and there were violators of order in both high and low groups and violators of assignment in all three groups in about equal proportions. When the percentages of off-task discussion were examined, both the highest (21%) and lowest (0%) percentages were found in the high group. But the high group had a much higher proportion of those off task 0% than did the medium or low group. Highs averaged only 4.5% off task compared to over 6% for both mediums and lows. However, the overall rate of student interactions focused on the task was exceptionally high.

There appeared to be little difference between groups in vocabulary use. Again the high group had both the highest and lowest users. The lows had the highest average use at 11.7 terms per page, but all groups were near an average of 10 terms per page.

Interestingly, high algebra achievers made more requests for confirmation or acknowledgment of understanding from their partners than did medium or low achievers, but lows averaged more than mediums. Requests were made most often during explanations by Explainers or Solvers. Perhaps the high's explanations were longer or more frequent and occasioned more checks for understanding.

In terms of unsolicited feedback in the form of statements of agreement, disagreement, encouragement, or criticism, medium algebra achievers on average gave more than either highs or lows. Low achievers gave the least. Much of the feedback was in the form of short agreements ("uh huh" and "okay"), and may be an indicator of attention to the task or active listening.

Joint productions were done by highs, mediums, and lows. Highs and mediums averaged the same number of joint productions, about three per session, but lows averaged only half that number. All groups had dyads who did no joint productions, but the low group had a higher proportion of them.

High algebra achievers tended to make fewer requests for help, direct or indirect, than medium or low achievers, who made on average about the same number. Medium and low achievers made more errors than high achievers, but differences were not big. Altogether, students made on average 2.5 errors each. Highs' average was a bit lower; mediums' and lows' was higher.

There were no obvious patterns in the giving of solicited explanations. All three groups averaged about the same, three per session. This rate seemed low, given the amount of talking students did. But it did not include the formal explanations students gave as

Explainers or Solvers following the script. Those explanations were generally not solicited, thus not coded in this analysis. The highest rate of giving solicited explanations was by a high achiever, but there were also rates of 0, 1, and 2 in the high group. There was only one 0 in each of the medium and low groups. Almost everyone gave some solicited explanations.

These patterns were validated in the following analysis and tended to be consistent with previous research.

Zero-order and partial correlations. Pearson product-moment correlations and partial correlations that controlled for prior mathematics achievement were calculated between each of the interaction variables and algebra achievement as measured by students' performance on the Chapter 8 test. Results of these calculations are listed on Table 1. Because of the relatively small sample size ($N = 22$) for this analysis and to facilitate comparisons with previous research that reported multiple significance levels, three levels of significance are reported for these results.

Two relationships deserve special attention: the strong correlation between achievement and joint productions and the negative correlation between achievement and making an error and receiving a question in response.

Table 1
Means, Standard Deviations, and Correlation Coefficients of Algebra Achievement, SAT-Math, and Interaction ($N = 22$)

Measure	M	SD	r with achvmt	Partial r[a]
Algebra achievement (Chapter 8 test score)	83.2	18.0		
Prior math achievement (10th grade SAT-Math stanine)	7.5	1.0	.59***	
Fidelity to roles (% score)	84.1	19.7	—.05	—.04
Off-task discussion (% of lines of transcript)	5.5	6.4	—.10	—.25
Vocabulary use (avg # terms/page of transcript)	10.6	3.6	—.15	—.19
Joint productions (frequency)	2.6	1.8	.31	.43**
Requests confirmation or acknowledgement of understanding	8.9	4.6	.27	.42*
Requests — receives no verbal feedback	1.4	2.1	.18	.24
Requests — receives solicited feedback	7.5	3.9	.23	.37*
Gives feedback other than answers or explanations	23.3	12.9	.23	.31
Gives solicited agreement, disagreement, encouragement, praise, criticism	7.5	3.9	.13	.03
Gives unsolicited agreement, disagreement, criticism	14.9	10.9	.22	.37*
Gives unsolicited encouragement, praise	0.9	1.4	.06	—.07
Receives encouragement, praise	1.0	1.6	—.54***	—.53**
Gives explanation (solicited)	3.4	3.0	.11	.08
Receives explanation	3.4	3.0	—.23	—.15
Makes error — receives explanation	0.2	0.5	.23	.38*
Makes direct or indirect help request — receives explanation	3.2	2.8	—.29	—.23
Receives no explanation	5.1	2.8	—.29	—.34
Makes error — ignored	0.9	1.0	.16	.06
Makes error — receives statement of confusion or hesitation	0.3	0.6	—.19	—.36
Makes error — receives question	0.7	1.2	—.45**	—.47**
Makes error — receives answer only	0.5	0.7	.08	.07
Makes direct or indirect help request — receives statement of confusion or hesitation	1.0	1.1	.15	.15
Makes direct or indirect help request — receives question	0.4	0.7	—.05	—.04
Makes direct or indirect help request — receives answer only	1.4	1.3	—.39*	—.35

[a] Partial correlation between interaction and achievement controlling for SAT-Math.

* $p < .10$ ** $p < .05$ *** $p < .01$

RESEARCH QUESTION 2

Under scripted cooperation, how are certain student characteris. (specifically, prior mathematics achievement, learning preference, study skills, and math anxiety) associated with specific verbal interactions?

To help answer this question, results of each of the student characteristic measures, administered to the experimental group prior to the study, were examined. Correlation coefficients were calculated between the characteristic measures and algebra achievement, then between the interaction variables and the characteristic measures.

Table 2
Means, Standard Deviations, and Correlation Coefficients of Student Characteristic Measures and Algebra Achievement (N = 22)

Student Characteristic Measure	*M*	*SD*	*r* with achvmnt
Algebra Achievement (Chapter 8 test)	83.2	18.0	
Prior Mathematics Achievement			
Grade-10 SAT-Math stanine	7.5	1.0	.59***
Learning Preference (LPSS)			
Individualized[a]	26.3	3.2	.23
Cooperative[a]	32.9	3.9	.03
Competitive[a]	26.3	3.8	.22
Mathematics Anxiety (MARS-A)[b]	215.6	52.7	−.03
Study Skills (LASSI)			
Attitude[c]	31.1	4.8	−.04
Motivation[c]	30.7	5.4	.41*
Time Management[c]	23.6	5.4	.25
Anxiety[c]	25.7	7.0	.15
Concentration[c]	23.5	5.6	.23
Information Processing[c]	25.7	4.4	.28
Selecting Main Ideas[d]	17.8	2.7	−.02
Study Aids[c]	23.4	4.6	.41*
Self Testing[c]	25.0	3.8	.61***
Test Strategies[c]	29.8	5.4	.18

[a]Maximum possible score = 40
[b]Maximum possible score = 490
[c]Maximum possible score = 40
[d]Maximum possible score = 25

* $p < .10$
** $p < .05$
*** $p < .01$

Student characteristic measures. The measures used were the Grade-10 Stanford Achievement Test (SAT) math subscale and three self-rating scales, the Learning Preference Scale for Students (LPSS), the Mathematics Anxiety Rating Scale-A (MARS-A), and the Learning And Study Skills Inventory (LASSI). Descriptive statistics are reported in Table 2 for the 22 students for whom there also existed interaction measures. Table 2 also lists the Pearson product-moment correlation coefficients between the characteristic measures and algebra achievement.

As Table 2 shows, students in this study had an average 7.5 stanine score on the 10th-grade SAT-Math. As was expected, the prior mathematics achievement was positively and significantly correlated with algebra achievement ($r = .59$, $p < .01$).

LPSS results show that this group of students tended to prefer cooperative modes of learning to individualized or competitive settings. Maximum and minimum possible subscale scores were 40 and 10, respectively; these students averaged almost 33 on the cooperative preference subscale versus 26 on the individualized and competitive subscales. The LPSS was designed to measure these preferences independently of one another. There were no forced-choice responses where students were required to select, for instance, either a cooperative response or a competitive one.

On the MARS-A, a high score indicated a high level of mathematics anxiety. The highest score possible was 490, the lowest was 98 (1 point for each of the 98 items). The math anxiety scores for this group of students were unexpectedly high, compared to the norms provided with the scale. The mean MARS-A score of about 215 fell between the 60th and 75th percentiles when compared to the 10th, 11th, and 12th grade norming groups (N = 323) (Suinn, 1979). Perhaps a more informative interpretation is the average response to the items: at 2.2 on a 5-point maximum scale, this average response was between "a little" and "a fair amount," which were the "2" and "3" response choices to the question of how anxious you would be made by the thing or experience described in an item ("4" and "5" were "much" and "very much"). Regardless of the level of math anxiety for these students, it seemed to be unrelated to the Chapter 8 algebra achievement under the scripted learning conditions.

The mean scores on the 10 LASSI scales were all at about the 45th percentile of the national norms for the college version of the LASSI, which has parallel items worded in a college context (high school norms were not available).

Interestingly, achievement was positively correlated with the LASSI scales for motivation ($r = .41$), study aids ($r = .41$), and self testing ($r = .61$). The Study Aids Scale addressed the degree to which students said they use or create support techniques or materials to help them learn and remember new information. Since the paired-learning script was presented to these students as a useful technique for learning mathematical material from a textbook, it fits the description of a study aid and was perhaps used as such by those who rated themselves high on the Study Aids Scale. The Self Testing Scale dealt with comprehension monitoring, which was the main function of the Checker role in the paired-learning script.

As part of the overall examination of the data, correlations were also calculated between the various student characteristic measures themselves. For this group of students, the Study Aids Scale was positively correlated with both the LPSS individualized subscale ($r = .37$, $p < .099$) and the cooperative subscale ($r = .48$, $p < .028$). In the *LASSI User's Manual* (Weinstein, Schulte, & Palmer, 1987) it is noted that using and creating study aids is especially helpful in autonomous learning situations (individualized mode). The questions on this scale also addressed using supplementary activities such as attending group review sessions or comparing notes with another student. These activities are like those in cooperative group work, so a positive correlation between the two scales is not unexpected.

For these students, the LPSS individualized subscale was also positively correlated with the LASSI Information Processing Scale ($r = .45$, $p < .040$) and the LPSS competitive subscale ($r = .48$, $p < .025$). Other correlations were found, which were not surprising, between students' SAT scores and the LASSI Motivation Scale ($r = .41$, $p > .060$) and between students' SAT and MARS-A scores ($r = -.52$, $p < .013$). Several of the LASSI scales were also correlated with one another.

Verbal interactions and student characteristic measures. More to the point of the research question, however, are the correlation coefficients listed in Tables 3 and 4, those between the interaction variables and the student characteristic variables just described—prior mathematics achievement, learning preference, math anxiety, and study skills. In Table 3, only those interaction variables that were shown to have a relationship with the LPSS or MARS-A scales are listed. Table 4 lists all 24 interaction variables used in the analysis, although only 14 of them showed any relationships with the LASSI scales that were significant at the .10 α level or below. Only 7 of the 10 LASSI scales were related to verbal interaction; the Attitude Scale, Anxiety Scale, and Test Strategies Scale were not and were omitted from Table 4.

What may be most interesting is the result not listed in the tables: there were no significant correlations between students' SAT-Math scores and their verbal interaction.

As Table 3 shows, there was a fairly strong relationship ($r = .45$) between students' scores on the individualized preference scale of the LPSS and giving feedback (solicited or unsolicited) other than answers or explanations. The given feedback seems to have served a monitoring function. Positive relationships were also evident between math anxiety and frequency of requests for confirmation or acknowledgement of understanding from a partner, with or without feedback ($r = .52$; with feedback $r = .48$). Apparently, the more anxious students were about mathematics, the more requests they made of their partners for agreement with what they were saying and doing.

As Table 4 shows, students' scores on several scales of the LASSI were correlated with various interactions. The Study Aids Scale relationship with off-task discussion (r = -.41) is understandable. Those most likely to use the resources in their environment to aid learning would be less likely to lose focus and get off-task. The notion of making maximum use of the learning environment, using study aids, is also consistent with the correlation (r = .44) between this scale and giving solicited feedback (agreement, disagreement, encouragement, or criticism). The correlations of the Self Testing Scale with receiving an explanation (r = -.69) or an answer only (r = -.59) to a help request indicate that those who rated themselves good at monitoring their own comprehension were apparently not the ones who made requests for help (directly or indirectly by expressing confusion or disagreement) in these verbal interactions. Perhaps being good at self testing helped them focus their help requests; they may have asked a few very direct questions rather than many general direct and indirect requests for help. The same sort of inverse relationship seems to have operated between the Information Processing Scale and receiving explanations. One other correlation is of interest, because it is the first finding of a relationship involving fidelity to the script roles: those who rated themselves high on the Time Management Scale were also the most faithful to the requirements of each of the script roles they performed (r = .43).

Table 3

Correlation Coefficients of Interaction with Learning Preference and

Mathematics Anxiety (N = 22)

Interaction	LPSS [a]			MARS-A [e]
	IND [b]	COOP [c]	COM [d]	
Requests confirmation or acknowledgement of understanding (with or without feedback)	—.01	—.22	—.17	.52**
Requests confirmation or acknowledgement of understanding and receives solicited feedback	—.05	—.40*	—.20	.48**
Gives feedback (solicited or unsolicited) other than answers or explanations (agreement, disagreement, encouragement, or criticism)	.45**	.07	.09	—.23
Gives unsolicited agreement, disagreement, or criticism	.51**	—.01	.19	—.14
Makes error and a receives statement of confusion or hesitation	—.09	—.10	—.41*	—.30

[a] Learning Preference Scale for Students
[b] Individualized Scale
[c] Cooperative Scale
[d] Competitive Scale
[e] Mathematics Anxiety Rating Scale—A

* $p < .10$
** $p < .05$
*** $p < .01$

Table 4
Correlation Coefficients Between Verbal Interaction and Study Skills (N = 22)

Interaction	Learning And Study Skills Inventory (LASSI) [a]						
	MOT	TMT	CON	INP	SMI	STA	SFT
Fidelity to roles (% score)	-.09	.43**	.36*	.34	.02	.11	.22
Off-task discussion (% of lines of transcript)	-.15	-.02	.03	-.34	.17	-.41*	-.02
Vocabulary use (avg # terms/page of transcript)	.18	.17	.30	.24	-.10	-.11	.06
Joint productions (frequency)	.27	-.18	-.19	.22	-.10	.21	.10
Requests confirmation or understanding	.34	.17	.20	.24	.05	.07	.25
Requests — receives no verbal feedback	.30	.22	.04	.23	-.10	.15	.32
Requests — receives solicited feedback	.25	.08	.22	.17	.12	.00	.12
Gives feedback other than answers or explanations	.25	.12	.07	.39*	-.06	.41*	.20
Gives solicited agreement, disagreement, encouragement, praise, or criticism	.16	.14	.10	.43**	.11	.44**	.30
Gives unsolicited agreement, disagreement, criticism	.19	.04	.01	.31	-.11	.32	.10
Gives unsolicited encouragement, praise	.35	.37*	.26	-.01	-.01	.06	.26
Receives encouragement, praise	-.18	-.08	-.03	-.23	.17	-.07	-.58**
Gives explanation (solicited)	.33	.03	.03	.05	-.30	-.17	.21
Receives explanation	-.05	-.26	-.39*	-.46**	-.08	-.16	-.66***
Makes error — receives explanation	-.02	-.22	-.44**	-.17	-.14	-.01	-.18
Makes direct or indirect help request — receives explanation	-.05	-.24	-.35	-.47**	-.06	-.17	-.69***
Receives no explanation	.02	-.24	-.21	-.16	.10	-.27	-.53**
Makes error — ignored	.31	-.09	-.02	.18	.15	.19	.19
Makes error — receives confusion or hesitation	.03	-.04	-.17	.11	.14	-.08	-.05
Makes error — receives question	-.20	-.18	-.26	-.22	-.26	-.31	-.44**
Makes error — receives answer only	-.20	-.18	-.02	.22	.43**	-.07	.07
Makes direct or indirect help request — receives statement of confusion or hesitation	.15	-.12	-.18	-.29	-.05	.04	-.11
Makes direct or indirect help request — receives question	.14	.10	.17	.08	-.03	-.39*	-.39*
Makes direct or indirect help request — receives answer only	-.12	-.11	-.05	-.23	.11	-.20	-.59***

[a] Key to reading LASSI scales
MOT: Motivation Scale
TMT: Time Management Scale
CON: Concentration Scale
INP: Information Processing Scale
SMI: Selecting Main Ideas Scale
STA: Study Aids Scale
SFT: Self Testing Scale

* $p < .10$ ** $p < .05$ *** $p < .01$

DISCUSSION

Analyses of all the data reflected an overwhelmingly positive student reaction to the paired-learning experience. Students were remarkably faithful to the script, even over time. The climate was supportive and students' interactions were focused on the academic tasks. Aside from describing the nature of students' verbal interaction under scripted cooperation, this study was done to determine (1) how specific verbal interactions were associated with algebra achievement and (2) how certain student characteristics were associated with those verbal interactions.

Comparisons to previous research.

The conditions of the present study differed substantially from those of the previous research, particularly in the areas of student grade level and group size, and especially by the imposition of a script on student interaction. The script altered what would have been "normal" interaction. For instance, requests for explanations were often unnecessary, since Explainers and Solvers were obligated to give explanations in the performance of their roles, anyway. Student questions were often not real questions but were devices that Checkers used to test Explainers' understandings or to prompt Solvers to catch their own errors. For these reasons, it was not expected that associations between interaction and achievement in this study would be directly comparable to previous research findings. The formalized explanation function and altered role of questioning, for instance, surely diluted and contaminated the measures of certain interaction variables that appeared superficially to be comparable to those of previous research. Nonetheless, there was enough unscripted interaction and enough real need for further explanation beyond what students gave playing their roles that relationships similar to, but probably not as strong as, those found in previous research might be expected. There were also some interaction variables peculiar to the use of the script, for which there were no comparable previous research findings. These variables included fidelity to the scripted roles, joint productions, making requests for confirmation or acknowledgement of understanding, giving and receiving feedback to such requests, giving and receiving encouragement/praise, and receiving questions as feedback to direct and indirect requests for explanations or errors. Some of these will be discussed.

Giving and receiving solicited explanations and confirmations. The findings listed in Table 1 are more or less consistent with previous research. Partial correlations that control for prior math achievement are generally in the expected direction but often not as strong as might be expected on the basis of previous research. In 11 of the 15 studies reviewed by Webb (1991), giving content-related explanations was positively and significantly correlated with achievement ($p < .05$). Such a strong relationship did not appear in the present study, however, where correlations between giving solicited explanations and algebra achievement were nonsignificant. Nor was giving solicited feedback in the form of agreement, disagreement, encouragement, or criticism significantly correlated with algebra achievement in this study. However, receiving such feedback, when solicited with a request for confirmation or acknowledgement of understanding, was significantly related to algebra achievement (positively).

This category of requesting confirmation or acknowledgement of understanding and receiving feedback in the form of agreement, disagreement, encouragement, or criticism was originally conceived to explore the responsiveness of partners to one another, their level of cooperation. There is no obviously comparable category in previous research, which leaves this result open to a couple of different interpretations. First, in this study these confirmation requests occurred most frequently in the course of students' explanations done in the performance of their roles, and these formal explanations were not coded and counted in the previously mentioned category, gives explanation (solicited). These answered requests may be interpreted as indications of the length, elaboration, or even effectiveness (in terms of meeting their partners' needs) of students' formal explanations. Thus, their positive correlation with algebra achievement could be appreciated in the context of giving explanations, which the previous research has shown to be positively related to achievement. This seems to be a reasonable interpretation given the high correlation between just making the confirmation request, regardless of the response, and algebra achievement.

Part of the interpretation problem with these particular results is the mixed nature of the requests and responses included in this category. It is a problem endemic to any kind of analysis of verbal discourse. It was usually impossible to tell whether a student's "Okay?" was either 1) a request for confirmation of the correctness of the statement just given, in which case the feedback was purely for the speaker's benefit, 2) a check on the partner's understanding of the statement, in which case the feedback often altered the course of the speaker's explanation so it would better serve the recipient and possibly benefit both speaker and recipient, or 3) both a request for confirmation and a request for acknowledgement of understanding by the partner. If one focuses on the confirmation function of these requests, a second interpretation is possible. These interactions could be interpreted as receiving the level of help that was requested. In Webb's (1991) review, the correlations between "responsive" sequences of behavior, wherein there was a match between the student's request for help and the kind of help received, were mixed with most being nonsignificant. This was the case in the two studies (Webb, 1982b; Webb & Kenderski, 1984) which included the category "makes error—receives explanation": results were positive but not significant. In the present study the partial correlation for the same relationship was much higher and significant (at $p < .10$).

Nonresponsive sequences of behavior. All the research reviewed by Webb (1991) shows negative partial correlations between "nonresponsive" sequences of behavior and achievement. Findings of the present study are consistent with this. In the overall group of interactions labeled "receives no explanation," the partial correlation with algebra achievement ($r = -.34$) approached significance ($p < .125$). Making an error and receiving a question in response was significantly ($p < .05$) correlated with algebra achievement ($r = -.47$). Since by the script used in this study, Checkers were instructed to catch errors and respond with at least three prompting questions before providing answers or explanations, this result could be very important to consider when revising the script for future use.

In the same general category of nonresponsive sequences of behavior, other results of the present study were consistent with previous research. The partial correlation of making an error and receiving a statement of mutual confusion or hesitation and algebra achievement was negative and approached significance ($p < .11$). Making a direct or indirect request for help (stating confusion or disagreement) and receiving an answer only was also negatively correlated with algebra achievement ($p < .11$).

Joint productions. Other results of this study have no direct correspondence to previous literature. For instance, there was a significant positive partial correlation ($p < .05$) between the frequency of joint productions and algebra achievement. During joint productions, students worked in tandem, more or less taking turns going through the steps of a problem or a textbook explanation. They often finished one another's sentences and talked at the same time.

These joint productions occurred most frequently during the Summary Questions on the worksheet, but some dyads used them during explanations of the textbook examples and for working Think-Aloud problems, too. Joint productions may amount to both students giving an explanation, and, since they are on the same train of thought, they both give and receive immediate feedback at a level of elaboration that closely matches what their partners need (responsive interaction).

Joint productions seemed to occur when partners were at the same level of understanding and not necessarily when they both understood the topic well. The two students working together seemed to be able to accomplish what one of them alone may not have been able to do. This fits rather well Vygotsky's (1978) notion of the "zone of proximal development," which is the term applied to the difference between what a child can do alone and what he or she can do with assistance. Students involved in joint productions could be thought of as operating within one another's zones of proximal development. Together they could provide both the component skills needed to solve the problem and the metacognitive information needed to coordinate, apply, and monitor the application of the skills. Working through the whole process together may have helped both students internalize the skills needed to solve such problems on their own in the future. As Vygotsky claimed (1962: 104), "What the child can do in cooperation today he can do alone tomorrow."

Receives encouragement. There is a striking negative correlation ($r = -.53$) between receiving encouragement or praise and algebra achievement. When one looks at the data distribution, it is understandable: few high achievers received any encouragement and most was received by low achievers. Also, the low overall frequency of encouragements allowed two extreme scores to disproportionately affect the analysis.

Unsolicited feedback. There was also a positive partial correlation ($r = .37$) between giving unsolicited feedback in the form of agreement, disagreement, or criticism and algebra achievement ($p < .10$). Such feedback may be interpreted as an indicator of active listening, in which case it's positive relationship to achievement would be consistent with the Peterson and Swing (1985) finding of a significant ($p < .05$) positive (partial) correlation between listening to others and achievement.

Off-task . .scussion. Finally, the correlation between off-task discussion and algebra achievement in this study was negative, as expected, but nonsignificant. In the literature the relationship between off-task discussion and achievement has been consistently negative and usually significant ($p < .05$).

Student Characteristic Measures. Results from previous research have shown that high-ability students gave the most explanations and that low-ability students were more frequently off-task (Webb, 1991). In this study there were no significant correlations between students' SAT-Math scores (ability) and their verbal interaction. The formalization of the explanation role and the use of dyads rather than small groups of students may have been factors in the finding for this study of no significant relationships where previous studies had found them.

Conclusions and Implications

The correlations found between interaction and algebra achievement in the present study were generally consistent with those of previous research done on small-group interaction and learning in mathematics classes. The relationships were often not as strong but were in the same direction as those in the literature. Since the script altered what would have been "normal" interaction, it made it difficult to compare some relationships found in this study with those cited in the literature. For instance, in the literature the giving of substantive explanations had a positive effect on the explainer's achievement. In this study the importance of giving explanations is probably underestimated; since everyone playing the Explainer role was required to give explanations, the only explanations coded were those given in response to direct or indirect requests for help outside of the Explainer role. Giving such explanations was not found to relate to either algebra achievement or prior mathematics achievement (ability), findings at odds with the literature on small-group interaction. More consistent with the literature, but not directly comparable because of the imposition of the script, was the significant negative correlation with achievement of the sequence "makes error-receives question in response." Although prompting questions were called for in the script under the Think-Aloud problem solving roles, in practice they did not work to help solvers. Those whose errors were met with explanations scored higher on the chapter test. Script revisions may be in order.

Script revisions may also be called for to take better advantage of the most interesting relationship suggested by this study: the strong positive correlation between achievement and the frequency of joint productions. A further analysis of the data may help determine what conditions promote joint productions. Variations of the script and training could be devised to set up those conditions.

The most interesting finding regarding student characteristics and interaction was that of no finding: none of the 24 categorized interaction sequences or behaviors was significantly related to ability (as measured by prior mathematics achievement). The imposition of the script on students' interaction seemed to have eliminated much of the variance in interaction found under the "normal" conditions reported in the literature. Students can be trained in interactions and behaviors believed to increase achievement to good effect. Results here demonstrate the usefulness of certain theoretically-based learning and interaction strategies as were included in the paired-learning script devised for and used in this study.

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