The Effects of Cued Interaction and Ability Grouping During Cooperative Computer-Based Science Instruction

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The purpose of this study was to investigate the effects of verbal interaction cues and ability grouping within a cooperative learning computer-based program. We blocked 231 eighth graders in a required science class by ability and randomly assigned them to homogeneous lower-ability, homogeneous higher-ability, or heterogeneous mixed-ability dyads. Each dyad was randomly assigned to a computer program that either did or did not contain verbal interaction cues designed to facilitate summarizing and explaining between partners. Results indicated that students using the cued version of the program performed significantly better on the posttest than students using the noncued version. Direct observation of student interaction indicated that students in cued dyads exhibited significantly more summarizing and helping behaviors than noncued students. Furthermore, higher-ability dyads exhibited significantly less off-task behavior than the other dyads. Implications for designing computer-based instruction for cooperative settings are provided.

☐ Teachers who integrate computers into their instruction usually have fewer machines than students. In fact, most computer labs contain fewer than 15 computers, and teachers who use computers in their own classroom ordinarily have only one or two computers at their disposal (Becker, 1991). Since the number of students usually exceeds the number of computers that can be used at one time, teachers must decide the best way to employ these limited resources. Many teachers solve hardware shortage problems by allowing more than one student to use a computer at a time, thus permitting more students to simultaneously use computers.

Unfortunately, very few computer programs exist that incorporate instructional strategies specific for learning groups. Software developers have generally assumed that computer-based instruction (CBI) programs should and would be utilized by individual users (Cosden, 1989). The individualistic nature of CBI programs may impact the interaction between group members and the computer program. This, in turn, may diminish the effectiveness of the program.

Since most CBI programs are not designed for group use, teachers must apply some type of small group learning strategy to the lesson in order to maximize the program's effectiveness for all group members. Today, the most common and widely researched small group learning strategy is cooperative learning.

In general, achievement results for cooperative learning-CBI studies are mixed, with more consistent results present for various non-

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achievement measures. Some studies have revealed significantly higher achievement scores for the cooperative groups (Dalton, Hannafin, & Hooper, 1989; Hooper, Temiyakarn, & Williams, 1993; Johnson, Johnson, & Stanne, 1985, 1986; Mevarech, Silber, & Fine, 1991; Mevarech, Stern, & Levita, 1987). Others have not found achievement effects for cooperative dyads versus individuals (Carrier & Sales, 1987; Makuch, Robillard, & Yoder, 1992; Trowbridge & Durnin, 1984; Whyte, Knirk, Casey, & Willard, 1991).

Although some studies have not indicated significant gains in achievement for cooperative dyads, most have reported some type of nonachievement results favoring groups. These included cooperative groups choosing more elaborative feedback (Carrier & Sales, 1987), spending most of the interaction time exhibiting task-oriented behavior (Johnson et al., 1985, 1986; Trowbridge & Durnin, 1984), and expressing more positive attitudes about working in groups at the computer (Hooper et al., 1993; Mevarech et al., 1987).

Inconsistent achievement results from cooperative learning-CBI studies may be due in part to other variables that have been shown to affect learning outcomes within cooperative learning environments. These variables include the type and amount of verbal interaction as well as the grouping of students according to academic ability.

Cooperative learning studies in which group member interactions have been recorded and analyzed indicate that achievement and attitude differences are related to the type and amount of verbal interaction between students within cooperative groups. In examining the results of numerous studies, Webb (1989) has determined that three distinct forms of verbal interactions correlate to improved cognitive abilities after a cooperative learning lesson. Students who give explanations to other group members, or who receive explanations from group members during a cooperative lesson tend to learn more from the lesson. Also, students who do not receive explanations in response to questions or errors tend to learn less from a cooperative lesson. Similarly, King (1989) examined why some cooperative groups were more successful than others at learning and applying problem-solving strategies. She found that successful groups asked more task-related questions, spent more time discussing strategy, and reached higher levels of strategy elaboration than unsuccessful groups. Fletcher (1985) reported that individuals from groups instructed to verbalize the decision-making process or reach consensus on a group answer demonstrated greater problem-solving ability than group members not instructed to verbalize throughout the lesson.

Recognizing the importance of verbal interaction between individuals within cooperative groups, Dansereau (1985) developed a systematic interaction and processing strategy that has provided a structured method for cooperative dyads learning text-based material. This strategy consisted of assigning two different roles to cooperative dyad members. After reading some instructional text, one student was instructed to verbally summarize the passage to the other group member, who was instructed to listen carefully and detect any errors or omissions. A number of studies testing the effects of this procedure have shown increased achievement for the pairs utilizing this structured interaction method (Lambiotte et al., 1987; McDonald, Larson, Dansereau, & Spurlin, 1985; O'Donnell, Dansereau, Hall, & Rocklin, 1987; O'Donnell, Rocklin, Dansereau, Hythecker, Young, & Lambiotte, 1987). Using a similar technique, Yager, Johnson, and Johnson (1985) found that groups given structured oral discussions through role assignments achieved higher posttest scores than groups participating in unstructured oral discussions.

In addition to verbal interactions, another variable that may influence outcomes in a cooperative learning setting is ability grouping. Ability grouping refers to the assignment of students into cooperative groups based on general academic ability. Heterogeneous groups are recommended in most cooperative learning models because they present opportunities for higher-ability learners to encourage and tutor lower-ability learners (Johnson, Johnson, & Holubec, 1990; Slavin, 1980). Creating heterogeneous ability groups within cooperative learning lessons has recently been supported by Slavin (1993) who reviewed 27 studies dealing with ability grouping and found little or no achievement differences between students grouped heterogeneously versus homogeneously by ability. The lower-ability students, however, did indicate more favorable attitudes toward learning when grouped with students of higher ability.

However, there are studies that have indicated that heterogeneous grouping may benefit one learner at the expense of the other learner. Webb (1982) reported that average-ability students performed worse when they were grouped with students of higher or lower ability than when they were grouped with other average-ability students. In addition, recent studies conducted with cooperative dyads using computers indicated that low-ability students benefited from heterogeneous grouping but high-ability students did worse compared to students grouped homogeneously by ability (Hooper, 1992; Hooper & Hannafin 1991).

Examining the research on ability grouping with cooperative groups participating in CBI programs, it appears that the amount of interaction between group members had an effect on the results. Hooper and Hannafin (1991) found that low-ability students grouped homogeneously interacted significantly less than students in the other groups. Hooper (1992) found that homogeneous grouping stimulated discussion between the high-ability students, but restricted discussion among low-ability groups.

The present study was designed to investigate the effects of verbal interaction cues and ability grouping within a cooperative learning-CBI science program. The major independent variable in this study was the presence of cues embedded throughout a CBI program designed to facilitate verbal interaction between two learners sharing one computer. Each cooperative dyad was assigned to a computer program that either did or did not contain these verbal interaction cues. The cues used in this study were similar to those demonstrating positive results in non-CBI studies (Dansereau, 1985; Yager et al., 1985). As each cooperative dyad assigned to the cued version progressed through the science CBI program, the computer prompted individuals within each dyad to verbally interact by directing them to summarize, explain, or listen to the other member of their dyad.

Ability grouping was another variable in the current study. All students participating in the study were assigned to one of three different types of dyads based on general academic ability. These dyads consisted of either homogeneous lower-ability, homogeneous higher-ability, or heterogeneous (mixed-ability) student pairs.

The dependent measures in this study included practice item performance, posttest performance, and attitudes toward the program and working with a partner. Measurements were also taken regarding the amount of time each dyad spent on different parts of the program. Time spent on instruction, practice problems, and interaction screens was measured separately. A sample of dyads was also videotaped, and the nature of interactions within each dyad was observed. These observations included the specific behaviors cued by the program (summarizing, explaining, identifying errors, and asking for help) as well as behaviors not addressed by the cues (receiving solicited and unsolicited help, verbal encouragement, and off-task behavior).

Based on results from studies investigating the effects of interaction cues similar to those used in this study as well as results from studies examining the effects of ability grouping within cooperative learning situations, two hypotheses were tested in the current study. One hypothesis was: students in dyads using the cued version of the computer program would spend more time verbally interacting and would perform better on the practice items and posttest than students using the noncued version. The other hypothesis was: lower- and higher-ability students grouped heterogeneously using the noncued version would earn lower practice items and posttest scores than similar ability students grouped homogeneously, but this effect would not occur between homogeneously and heterogeneously grouped lower- and higher-ability students using the cued version of the program.

METHOD

Subjects

Subjects were 231 students from a junior high school in a middle-class socioeconomic, metropolitan area. They were enrolled in a required one-semester, eighth-grade general science class. This science course followed a curriculum that incorporated the use of cooperative learning strategies into most laboratory investigations and activities.

Materials

A computer-based instruction (CBI) science program entitled *Designing Controlled Experiments* was the source of instruction for this study. This Hypercard-based program was developed by the first author and consisted of four distinct parts:

1. The program introduction
2. Lesson One: The Steps in the Scientific Method
3. Lesson Two: The Parts of a Controlled Experiment
4. Lesson Three: Designing Controlled Experiments

The program introduction consisted of eight information screens which provided an orientation for the students regarding the successful use of the program. This introduction prompted the students to enter their first names, thus enabling the program to call on students by name to perform specific tasks throughout the program. Both students were then encouraged to help each other learn the information presented in the three lessons by reviewing some helpful cooperative learning roles to assume and share throughout the program. These roles included the *summarizer* who verbally summarizes a unit of information, the *explainer* who explains examples presented in the program, and the *listener* who listens carefully to the summarizer or explainer and asks questions about things that are unclear, left out, or in error. Because the students had experience with formal cooperative learning techniques, these roles were already familiar to them.

The introduction also informed the students that two scores earned for this CBI activity were to be counted toward their semester grade. One score came from the number of practice items answered correctly by students together on the practice problems presented throughout the program. The other score came from each student's individual performance on a written posttest administered on the day following the completion of the program.

The entire computer program was primarily linear in nature. Students progressed to new screens by clicking on the "next" arrow. The only occasions when students could view previous screens were within the information presentation sections of the program. There was no other type of learner control in this program.

The three lessons that followed the introduction were similar to each other in structure. These lessons are described below.

Lesson One: The Steps in the Scientific Method

The first lesson in the program taught the steps in the scientific method and was broken up into two parts. The first part covered making observations, identifying problems, and choosing hypotheses. It included 20 information, example, and review screens. Six multiple-choice practice problems were then presented, and a group score was displayed. Immediate feedback for all multiple-choice practice items throughout the program included positive reinforcement for correctly answered problems and knowledge of the correct response for those problems answered incorrectly. The second part of Lesson One included 24 information, example, and review screens covering making predictions, designing experiments, and analyzing data/conclusions. Three multiple-choice practice problems covering the three verbal information objectives for the second part were then presented followed by a display of the total number of practice problems answered correctly.

Lesson Two: The Parts of a Controlled Experiment

The second lesson covered the parts of a controlled experiment. This lesson was also divided into two parts, with practice problems and group scores presented after the instruction. The first part of the second lesson consisted of 23 information, example, and review screens covering independent and dependent variables. Three multiple-choice practice items were presented following the first part of Lesson Two. The second part of Lesson Two presented 26 information, example, and review screens covering extraneous variables, variable groups, and control groups. Five multiple-choice practice items were presented after the instruction, followed by an indication of the total number of practice problem items answered correctly for the first two lessons.

Lesson Three: Designing Controlled Experiments

The third lesson was comprised of only one part. This lesson consisted of 33 information, example, and review screens presenting the four steps to be followed when designing a controlled experiment:

1. Identify the independent and dependent variables
2. Determine the type of test to be performed
3. Determine at least three extraneous variables to be controlled between experimental groups
4. Describe the control and variable groups by listing and labeling all variable types within each group

Two constructed-response practice problems were then presented after the instruction. These constructed-response items were evaluated by the students based on a set of criteria they used to judge various aspects of their answers. For example, after a group had listed and labeled the variables for an experiment designed to test a given hypothesis, the computer asked: "Does your variable group contain [appropriate variable name], and is it labeled as the independent variable?" The computer asked similar questions about the dependent and extraneous variables. The students were directed to click on Yes or No buttons as each statement applied to their constructed response. It was not assumed, however, that the students would necessarily evaluate their answers honestly or correctly. Their responses were recorded by the computer and printed for future evaluation by the first author. Any scoring discrepancies were adjusted before analysis of these data. Although the previous 17 multiple-choice practice items were worth one point each, these final two constructed-response practice items were worth five points each. The constructed-response items were worth more points than the multiple-choice items because they required the learners to apply at least five different skills taught throughout the program. Lesson three concluded by displaying the total number of practice problems answered correctly by the group for the entire program.

The computer program included the primary elements necessary for cooperative learning as prescribed by Johnson and Johnson (1989). Individual accountability was fostered by requiring each student to take the posttest individually. The potential for positive interdependence was established by having the students share the practice problem score. Providing an opportunity for group members to interact was addressed in a number of ways throughout the program. The computer program provided the students with many opportunities to verbally interact by sharing answers, ideas, explanations, and summaries. Students were also prompted to share the mouse and keyboarding responsibilities. These strategies promoted interaction as well as contributed to the overall level of interdependence.

Two versions of *Designing Controlled Experiments* were developed for this study. The introductory material, instructional content, and practice problems were exactly the same in the two versions. However, one version (cued) included explicit group member interaction cues embedded throughout the program while the other (noncued) did not include these cues. The cued interaction version included two types of group member interaction cues. One type of cue was presented immediately preceding the practice problems for each lesson. These were content summary cues. The other type of interaction cues was presented along with certain examples throughout the program. These were explaining cues. The program assigned each student participating in the cued version of the program the role of summarizer six times, the role of explainer two times, and the role of listener eight times throughout the entire three-lesson program. Figure 1 illustrates the differences between the cued and noncued versions for a typical summary screen. Figure 2 illustrates the differences between the cued and noncued versions in a typical explanation screen.

Both the content summary and explaining cues prompted the students to verbally interact with their partners. The noncued version of the program provided the same opportunities for students to interact, but the program did not explicitly prompt the students to do so.

Dependent Measures

There were three dependent measures in this study. These measures included embedded practice item performance, posttest performance, and student attitudes.

Seventeen multiple-choice and two constructed-response practice items were administered by the computer throughout the program. All answers to the practice items were recorded by the computer. Although the students evaluated their own answers for the two constructed-response items, their actual answers were evaluated by the first author and graded according to a set of criteria. Students could earn from zero to five points for each question. These practice problems represented a group-based measure.

A paper-and-pencil posttest was administered on the day following the completion of the computer program. This 28-item test included labeling, multiple-choice, and constructed-response questions similar to the practice problems presented in the CBI program. Posttest items included a mix of questions measuring knowledge of the content covered in the program as well as application questions. The knowledge items represented performances requiring the learner to state or identify concrete or defined concepts. For example, one item asked the students to identify the definition of *hypothesis* from a list of statements. Application questions represented performances requiring the learner to apply rules to identify instances of concepts or to solve problems (see Gagné, 1985). Many of the constructed-response items were application questions. An example of this type of item was a question in which students were given a problem, hypothesis, and prediction statements about goldfish growth and then asked to design part of an experiment to test the hypothesis by listing and labeling variables for both control and variable groups. The KR-21 reliability of all combined posttest items was .87.

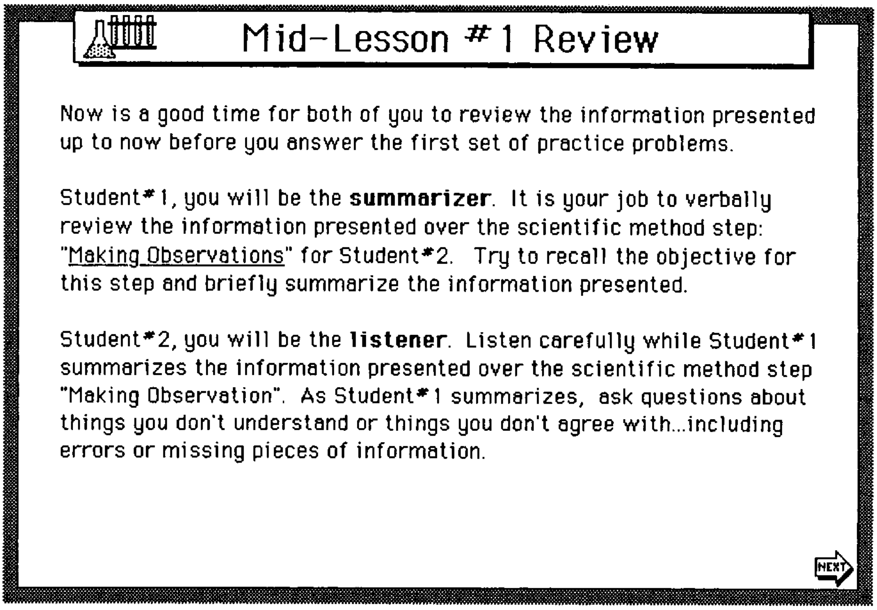
Each posttest item was worth one point, with the exception of two application items which were worth two points each because they consisted of two parts and required two separate answers. There were a total of 15 knowledge-item points, and 15 application-item points. All posttests were scored by the first author.

A 10-item Likert-scale attitude survey was administered prior to the posttest. Statements such as "I tried hard to understand the information presented in the computer program," " I am confident that I will do well on the final test," and "I enjoyed working with a partner" measured student interest, motivation, confidence, enjoyment, and attitudes toward working with a partner. The Cronbach Alpha reliability of this attitude survey was .78.

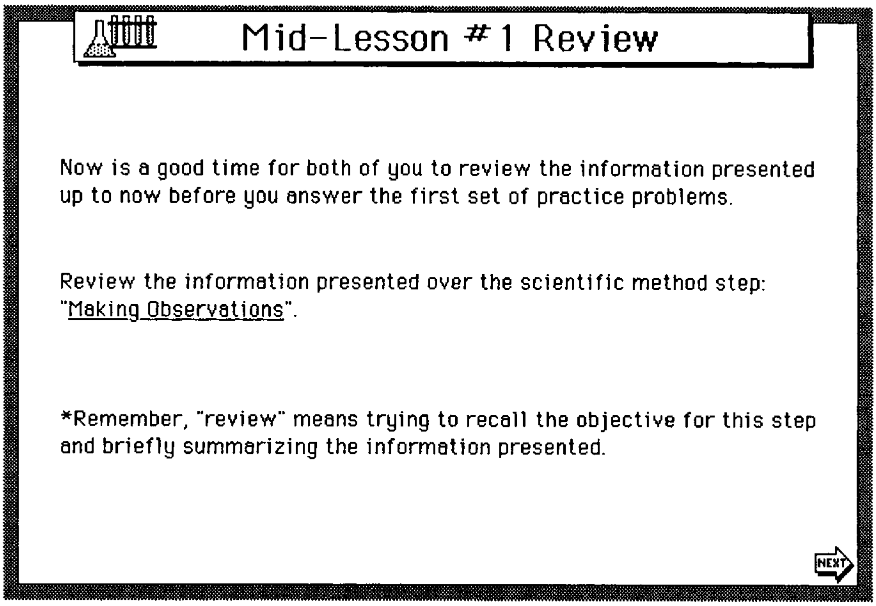
Other Measures

Other measures in this study included time data recorded by the computer, and interaction behavior as recorded by a video camera and tape recorder. The amount of time spent viewing the information screens was captured

Figure 1 ☐ Sample summary screens in the cued and noncued versions.

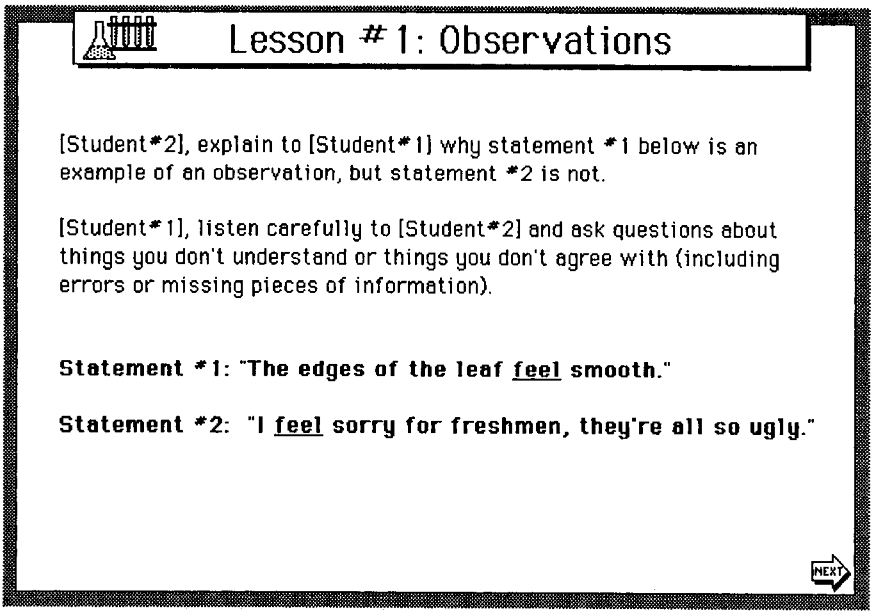


Summary screen: Cued Version

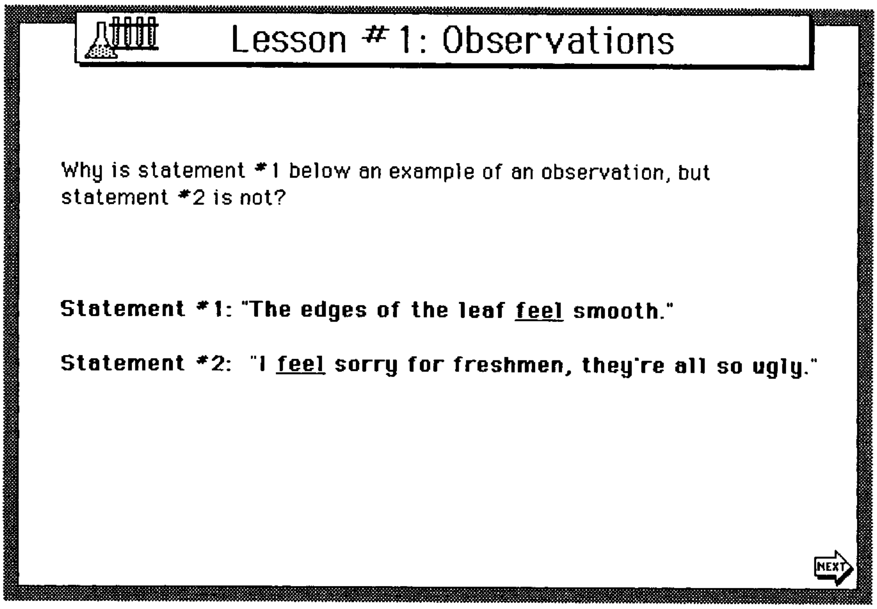


Summary screen: Noncued Version

Figure 2 ☐ Sample explanation screens in the cued and noncued versions.



Explanation screen: Cued Version



Explanation screen: Noncued Version

by the computer for each dyad. The computer also recorded the elapsed time on the interaction screens as well as the amount of time spent answering the practice items. The total time spent going through the complete three-lesson program was also calculated.

All interaction behaviors were observed and evaluated by the first author while examining videotapes of a sample of students participating in the program. Nine different types of interaction behaviors were recorded and tabulated from the videotaped observations. These interaction-behavior types were determined prior to making the observations and were similar to those behavior categories identified and used by Webb (1982) and King (1989). Some of these categories represented those behaviors addressed in the cues, including summarizing, explaining, asking for help, and identifying errors. Other categories represented behaviors that were not specifically addressed in the cues, but they contributed to one partner helping the other understand the material. These helping behaviors included giving solicited and unsolicited help, checking for understanding, and offering verbal encouragement. In addition, any incidents of students being off-task during the interaction screens were recorded. Off-task behavior included talking to members of other dyads, talking to partners about things unrelated to the program, leaving the computer, looking at students from other dyads for sustained periods of time while the other partner read the screens and moved on, and reading or writing material unrelated to the program. Interaction behaviors were identified and classified from the videotaped observations only when students were viewing the interaction screens during one lesson. Separate observations were analyzed for each individual within every sample dyad.

Procedure

This study included six different treatment groups. Subjects were blocked by ability and randomly assigned to lower-ability, higher-ability, or mixed-ability dyads. Ability blocking was based on each student's Iowa Test of Basic Skills (ITBS) composite score for seventh grade. ITBS scores for each subject were ranked and a median split was used to determine the lower and higher-ability subject pools. The median composite score for subjects in this study was 24 and the national percentile rank was 58%. Data for subjects across the United States indicated that the mean composite score for the ITBS was 22 and the percentile rank 50%. Seventeen subjects did not have ITBS scores available, and each of their placements into the lower or higher-ability subject pool was based on grade-point average and teacher confirmation of general classroom ability. The lower-ability dyads were comprised of two students randomly selected from the lower-ability subject pool. The higher-ability dyads were comprised of two students randomly selected from the higher-ability subject pool. The mixed-ability dyads were comprised of one student randomly selected from the lower-ability subject pool and one student randomly selected from the higher-ability subject pool. All dyads were then randomly assigned to either the cued or noncued versions of the program. There was a total of 256 students (128 dyads) at the beginning of the study. Data from 25 students were unusable due to absences or severe behavior problems during the study.

All the students participating in this study had experienced at least two months of working in formal and informal cooperative learning groups. The general science program at the junior high school emphasized cooperative group work using the Circles of Learning model of cooperative learning (Johnson et al., 1990). Students had been taught and evaluated on such essential collaborative skills as using each other's first names, staying with assigned groups, remaining on task, and carrying out assigned roles during laboratory activities. Students also had some experience participating in roles such as summarizer, listener, and explainer. The students had experience with various reward interdependence structures, including group grades for laboratory reports, projects, and homework assignments. Making individuals within cooperative groups responsible for specific materials and resources was also a strategy emphasized in the eighth-grade science program.

All dyads were given three 55-minute class periods on three consecutive days to complete the CBI program. Each dyad was given the first class period to complete the introduction and Lesson One, another class period on the second day to complete Lesson Two, and one final class period on the third day to complete Lesson Three. The attitude survey followed by the posttest was administered on the fourth day of the study.

Eight to twelve dyads moved from their regular science classroom to a large computer room to work on the CBI program at one time. The students were informed that the program presented important information necessary for succeeding in the science class, and that the points earned would have an impact on their individual grades for the course. The students were also informed that all the directions for successfully completing the program were presented at the beginning of the program, and they had to read all the information very carefully. The computer was the only source of continual monitoring for most groups. However, two dyads in every class were also videotaped. The subjects' science teacher was in the computer room at all times to help get the program started and to answer any procedural questions.

Before sitting down at the computer on the first day of the program, each member of a dyad was randomly designated Student #1, or Student #2. When the dyad began either version of the program, each member individually typed his or her name into the Student #1 or Student #2 field. Each dyad worked at its own pace throughout a 55-minute class period. Students in dyads finishing early on any of the three days were sent back to their regular science class without proceeding to the next lesson. Each member of every dyad individually completed the attitude survey and a written posttest on the fourth day.

Students comprising six dyads from each of the six different treatment groups were randomly selected to be monitored by video camera. These videotaped dyads were informed that their science teacher was interested in studying how students work together at the computer, but their individual behavior during the program was not going to affect the grade they earned. The data from this sample of 72 students were used to determine any differences in the type of interactions occurring throughout the program.

Design and Data Analysis

This study used a posttest-only control group design. It was a 2 (cued interactions versus noncued interactions) × 3 (lower-ability dyads, higher-ability dyads, and mixed-ability dyads) factorial design. Both the cueing and grouping variables were between-subjects variables. In addition, data were also analyzed using separate 2 (cued interactions versus noncued interactions) × 2 (homogeneous versus heterogeneous grouping) factorials designs for both the lower-ability and higher-ability students.

Analysis of variance (ANOVA) was conducted on practice item performance for the dyads. Time data were analyzed using multivariate analysis of variance (MANOVA) for time spent on the information screens, time spent on the interaction screens, and time spent on the practice screens, and separate follow-up univariate analyses were conducted on each of these time categories as well as total program time. The practice item and time analyses represented the only group-based measures analyzed. The individual measures analyzed included posttest performance, attitude survey responses, and individual behaviors observed in the videotapes sample. ANOVA was used to analyze posttest performance. The attitude survey results were analyzed using MANOVA, with each survey item constituting a separate dependent measure. The observation data on group member interaction were also analyzed using MANOVA, with total cued behaviors, total helping behaviors, and total off-task behaviors representing separate dependent measures.

RESULTS

Posttest Performance

The overall mean for posttest performance was 19.30 ($SD = 6.56$). Means and standard deviations for individual posttest performance are reported in Table 1. The mean posttest score was 20.63 ($SD = 6.56$) for students who used the cued version of the CBI program and 18.03 ($SD = 6.33$) for those who used the noncued version. Table 1 also shows that the mean posttest score was 15.45 ($SD = 4.26$) for students in the homogeneous lower-ability dyads, 18.65 ($SD = 6.39$) for those in the heterogeneous (mixed-ability) dyads, and 23.90 ($SD = 5.63$) for those in the homogeneous higher-ability dyads.

ANOVA indicated that subjects who used the cued version of the program performed significantly better on the posttest than those who used the noncued version, $F(1, 225) = 12.97$, $p < .001$. ANOVA also indicated a significant performance difference between subjects in the three ability groups, $F(2, 225) = 45.92$, $p < .001$. Post hoc analyses using Tukey HSD pairwise comparisons revealed that the mean performance scores between each of the three ability groupings were significantly different ($p < .001$). Subjects assigned to higher-ability dyads performed significantly better than those in the mixed dyads and those in the lower-ability dyads. In addition, subjects in the mixed dyads performed significantly better than those in the lower-ability dyads. ANOVA did not indicate a significant interaction between version and ability grouping when individual performance scores were analyzed.

The posttest scores of lower and higher-ability students were analyzed separately to determine the effect of homogeneous versus heterogeneous grouping on performance. Table 2 reveals that the mean posttest score was 15.51 ($SD = 4.62$) for lower-ability students in homogeneous dyads and 14.85 ($SD = 4.33$) for lower-ability students in heterogeneous dyads. The mean posttest score was 23.92 ($SD = 5.63$) for higher-ability students in homogeneous dyads and 22.46 ($SD = 5.87$) for higher-ability students in heterogeneous dyads.

Separate 2 (Version) × 2 (Grouping) ANOVAs were conducted on the posttest scores of lower and higher-ability students. ANOVA indicated that lower-ability students who used the cued version performed significantly better on the posttest ($M = 16.49$, $SD = 4.83$) than lower-ability students who used the

Table 1 ☐ Means and Standard Deviations for Posttest Performance by Version and Ability Grouping

		Ability Grouping			
Version		*LL*	*LH*	*HH*	*Total*[a]
Cued	*M*	16.83	19.79	25.29	20.63
	(SD)	(4.92)	(6.24)	(5.54)	(6.56)
	n	40	38	38	116
Noncued	*M*	14.08	17.51	22.51	18.03
	(SD)	(3.84)	(6.40)	(5.44)	(6.33)
	n	37	41	37	115
Total	*M*	15.45	18.65	23.90	19.30
	(SD)	(4.26)	(6.39)	(5.63)	(6.56)
	n	77	79	75	231

Note: LL = Homogeneous lower-ability dyads, LH = heterogeneous (mixed-ability) dyads, HH = homogeneous higher-ability dyads.

[a] 30 possible posttest points.

Table 2 ☐ Posttest Means and Standard Deviations for Lower and Higher-ability Students

Ability Grouping[a]		Version: Cued	Version: Noncued	Total
Lower Ability				
Homogeneous	*M*	16.83	14.08	15.51
	(SD)	(4.92)	(3.84)	(4.62)
	n	40	37	77
Heterogeneous	*M*	15.79	14.00	14.85
	(SD)	(4.66)	(3.92)	(4.33)
	n	19	21	40
Total	*M*	16.49	14.05	15.28
	(SD)	(4.83)	(3.84)	(4.51)
	n	59	58	117
Higher Ability				
Homogeneous	*M*	25.29	22.51	23.92
	(SD)	(5.54)	(5.44)	(5.63)
	n	38	37	75
Heterogeneous	*M*	23.79	21.20	22.46
	(SD)	(4.96)	(6.49)	(5.87)
	n	19	20	39
Total	*M*	24.79	22.05	23.42
	(SD)	(5.36)	(5.81)	(5.73)
	n	57	57	114

Note: [a] Refers to homogeneous (LL or HH) or heterogeneous (LH) dyads.

noncued version ($M = 14.05$, $SD = 3.84$), $F(1,113) = 7.01$, $p < .01$. However, ANOVA did not reveal a significant difference between students in the homogeneous and heterogeneous dyads for lower-ability students. The second posttest ANOVA indicated that the higher-ability students using the cued version performed significantly better on the posttest ($M = 24.79$, $SD = 5.36$) than the higher-ability students who used the noncued version ($M = 22.05$, SD = 5.81), $F(1,110) = 5.90$, $p < .05$. ANOVA did not reveal a significant difference between higher-ability students in the homogeneous and heterogeneous dyads.

Attitudes

Individual attitudes toward the program were measured using a 10-item Likert-scale survey. Responses for each item ranged from 1 (strongly agree) to 4 (strongly disagree). The results indicated that the students generally enjoyed working with a partner ($M = 1.88$, $SD = 0.95$) and wanted to work with a partner again to do another science lesson on the computer ($M = 1.82$, $SD = 0.91$). Most students also reported that they tried hard to understand the information presented in the computer program ($M = 1.89$, $SD = 0.69$). However, many students did not feel the information was easy to understand (M = 2.32, SD = 0.82). Students also responded negatively to the continuing motivation statement about wanting to learn more about designing experiments ($M = 2.54$, $SD = 0.79$).

All 10 attitude survey items were analyzed using MANOVA. This analysis indicated no significant differences in overall, collective responses by cued versus noncued versions,

$F(10, 214) = 1.36$, $p > .05$, or ability grouping, $F(20, 428) = 1.34$, $p > .05$. Despite the nonsignificant MANOVA results, individual attitude item results were explored. Univariate analyses conducted on each survey item revealed that subjects who received the cued version of the program ($M = 2.44$, $SD = 0.07$) responded more favorably than those who received the noncued version ($M = 2.65$, $SD = 0.07$) to the statement, "I would like to learn more about designing experiments," $F(1, 223) = 4.18$, $p <$ 05.

Univariate analyses also revealed that students in the higher-ability dyads ($M = 2.00$, $SD = 0.09$) responded more favorably than those in the mixed-ability dyads ($M = 2.33$, $SD = 0.09$) and those in the lower-ability dyads ($M = 2.42$, $SD = 0.09$) to the statement, "I am confident that I will do well on the final test," $F(2, 223) = 6.46$, $p < .05$. When the responses to this survey item were analyzed separately by ability level, it was determined that the higher-ability students in the homogeneous dyads ($M = 1.92$, $SD = 0.12$) responded more favorably than the higher-ability students in the mixed-ability dyads ($M = 2.34$, $SD = 0.17$), $F(1, 109) = 4.49$, $p < .05$. There were no other significant differences in attitude responses by version or grouping.

Practice Performance

Means and standard deviations for practice performance are reported in Table 3. These data reveal that the mean practice score was 18.36 ($SD = 4.98$) for dyads who used the cued version of the CBI program and 16.17 ($SD = 5.78$) for those who used the noncued version. Table 3 also shows that the lower-ability dyads had a mean practice score of 13.13 ($SD = 4.98$), the mixed-ability dyads averaged 18.42 ($SD = 5.06$), and the higher-ability dyads averaged 20.25 ($SD = 3.69$) for practice performance.

ANOVA indicated that dyads who used the cued version performed significantly better on the practice items than those who used the noncued version, $F(1, 106) = 6.50$, $p < .01$. ANOVA also indicated a significant effect due to ability grouping, $F(2, 106)=24.59$, $p < .001$. Tukey HSD post hoc analysis of practice scores revealed that the lower-ability dyads performed significantly worse on the practice items than either the mixed-ability dyads or

Table 3 ☐ Means and Standard Deviations for Practice Performance by Version and Ability Grouping

		Ability Grouping			
Version		*LL*	*LH*	*HH*	*Total*
Cued	*M*	14.85	19.33	20.89	18.36
	(SD)	(5.14)	(4.23)	(3.32)	(4.98)
	n[a]	20	18	19	57
Noncued	*M*	11.41	17.50	19.61	16.17
	(SD)	(4.18)	(5.67)	(4.05)	(5.78)
	n	17	20	18	55
Total	*M*	13.13	18.42	20.25	17.31[b]
	(SD)	(4.98)	(5.06)	(3.69)	(5.45)
	n	37	38	37	112

Note: LL = Homogeneous lower-ability dyads, LH = heterogeneous (mixed-ability) dyads, HH = homogeneous higher-ability dyads.

[a] Each *n* represents the number of dyads in each cell.

[b] There were 27 possible practice item points.

higher-ability dyads ($p < .001$). Post hoc analyses did not reveal a significant difference in practice performance between the mixed-ability and higher-ability dyads. No significant differences for interactions between version and ability grouping were found.

Time on Instruction

Time spent using the program is reported in Table 4. These data reveal that the average amount of time spent on the computer program was 83.7 minutes for dyads assigned to the cued version and 78.0 minutes for dyads assigned to the noncued version. The lower-ability dyads averaged 81.4 minutes, the mixed-ability dyads averaged 84.0 minutes, and the higher-ability dyads averaged 77.5 minutes on the program.

A MANOVA was performed on the time spent on the instruction, interaction, and practice screens. This test indicated significant differences by version and ability grouping, $F(4, 95) = 867.26$, $p < .001$. Follow-up univariate analyses indicated that dyads assigned to the cued version spent significantly more time ($M = 7.8$ minutes) on the summary and explanation interaction screens than dyads assigned to the noncued version ($M = 5.1$ minutes), $F(1, 99) = 24.70$, $p < .001$.

Univariate tests also revealed significant differences between the three different ability groups in time spent on the instruction screens, $F(2, 99) = 3.20$, $p < .05$, and practice screens, $F(2, 99) = 7.03$, $p < .001$. Tukey HSD post hoc analyses of these differences indicated that the higher-ability dyads spent significantly less time on the instruction ($M = 45.6$ minutes) than either the mixed-ability dyads ($M = 50.7$ minutes) or the lower-ability dyads ($M = 53.0$ minutes), $p < .05$. The post hoc analyses also indicated that the lower-ability dyads spent significantly less time on the practice items ($M = 21.6$ minutes) than either the mixed-ability dyads ($M = 25.6$ minutes) or the higher-ability dyads ($M = 25.0$ minutes), $p < .01$. No other significant differences were found for time data.

Table 4 ☐ Mean Time Spent on Instruction, Interaction, and Practice Screens by Version and Ability Grouping

		Ability Grouping			
Version	*Type of Screens*	*LL*	*LH*	*HH*	*Total*
Cued	Instruction	57.0	50.1	48.2	51.8
	Interaction	7.6	8.2	7.8	7.8
	Practice	21.1	26.1	26.1	24.4
	Total	84.1	84.5	82.7	83.7
Noncued	Instruction	48.5	51.3	42.8	47.5
	Interaction	4.7	5.2	5.4	5.1
	Practice	22.2	25.1	23.9	23.8
	Total	78.1	83.7	72.1	78.0
Total	Instruction	53.0	50.7	45.6	49.8
	Interaction	6.2	6.7	6.7	6.5
	Practice	21.6	25.6	25.0	24.1
	Total	81.4	84.0	77.5	80.9

Note: All time in minutes. LL = Homogeneous lower-ability dyads, LH = heterogeneous (mixed-ability) dyads, HH = homogeneous higher-ability dyads.

Interaction Behaviors

A sample of 72 subjects from 36 dyads were observed as they worked through the summary and explanation screens of one lesson and interaction behaviors were recorded. These interaction behaviors were grouped into the three categories of cued behaviors, helping behaviors, and off-task behaviors for purposes of analysis.

The cued behaviors represented those behaviors specifically addressed by the cues directed at each dyad member during the summary and explanation screens. These behaviors included summarizing, explaining, identifying errors, and asking for help when needed. Table 5 presents the total number of instances recorded for students in the sample dyads for each of the cued behaviors. These data reveal that students in the cued version exhibited a total of 101 cued behaviors, while students in the noncued version exhibited 44 cued behaviors.

A MANOVA was performed on the four different behaviors within the cued behavior category. This test indicated a significant overall difference between versions, $F(4, 63) = 4.60$, $p < .01$. Follow-up univariate analyses indicated that subjects in the cued dyads summarized significantly more than those in the noncued dyads, $F(1, 66) = 16.91$, $p < .001$. Subjects in dyads who used the cued version also asked for help more than those who used the noncued version, $F(1, 66) = 7.66$, $p < .01$. No other cued behaviors were significantly different between versions. A significant main effect was not found for ability grouping, nor was an interaction detected.

Table 5 also reports the instances of helping behaviors observed for members of the sample dyads. These behaviors were not specifically cued by the computer program; they included giving solicited help, giving unsolicited help, checking for partner understanding, and encouraging partner. These data reveal subjects in the dyads who used the cued version gave solicited help 14 times and unsolicited help 12 times. No instances of solicited help and 3 instances of unsolicited help were observed for subjects in the dyads who used

Table 5 ☐ Instances of Interaction Behaviors for Sample Dyads by Version

	Version	
Type of Interaction Behavior	*Cued*	*Noncued*
Cued Behaviors		
Summarized	46	12
Explained	32	27
Identified errors	3	0
Asked for help	20	5
Total	101	44
Helping Behaviors		
Gave solicited help	14	0
Gave unsolicited help	12	3
Checked for partner's understanding	7	2
Encouraged partner	15	2
Total	48	7
Off Task Behaviors	11	9

Note: The total number of each interaction behavior is reported for a sample of 36 students assigned to the cued version and 36 students assigned to the noncued version.

the noncued version. Subjects in the dyads who used the cued version of the program checked for understanding 7 times, while those who used the noncued version checked for understanding 2 times. Subjects in the cued dyads encouraged their partner 15 times, while those in the noncued dyads encouraged their partners 2 times. There was a total of 48 instances of helping behaviors for subjects in dyads using the cued version, and 7 instances for dyads who used the noncued version.

A MANOVA was performed on the four different behaviors within the helping behavior category. This test indicated a significant overall difference between versions, $F(4, 63) = 3.22$, $p < .05$. Follow-up univariate analyses indicated that subjects in dyads who used the cued version of the program gave more solicited help than those who used the noncued version, $F(1, 66) = 8.26$, $p < .01$. Subjects in the cued dyads also gave more unsolicited help than those in the noncued dyads, $F(1, 66) = 4.77$, $p < .05$. Subjects in cued dyads also encouraged their partners more than those in the noncued dyads, $F(1, 66) = 6.52$, $p < .05$. No other helping behaviors were significantly different between versions. A significant main effect was not found for ability grouping, nor was an interaction detected.

The third category of recorded interactions was off-task behavior. Table 5 also reports the instances of observed off-task behavior for the sample of dyads. These data reveal that subjects in dyads who used the cued version of the program were off-task 11 times, while those who used the noncued version were off-task 9 times. ANOVA indicated that this difference was not significant. However, there was a significant differences in number of off-task behaviors between ability groups, $F(2, 69) = 2.96$, $p < .05$. Subjects in the lower-ability dyads were off-task 10 times, subjects in the mixed-ability dyads were off-task 10 times, and subjects in the higher-ability dyads were never off-task during the interaction screens. Post hoc analyses using Tukey HSD pairwise comparison revealed that subjects in the lower-ability and mixed ability dyads were off-task significantly more than subjects in the higher-ability dyads ($p < .05$).

Because a sample of only 36 dyads was used, there were not enough subjects to conduct analyses of differences in interaction behaviors between heterogeneously and homogeneously grouped higher and lower-ability students.

DISCUSSION

The purpose of this study was to investigate the effects of verbal interaction cues and ability grouping within a cooperative learning-CBI science program. Cooperative dyads used a computer program that either did or did not contain verbal interaction cues designed to facilitate summarizing and explaining between partners at various points throughout the program. All students were assigned to one of three different types of dyads based on general academic ability. These dyads consisted of lower-ability, higher-ability, or mixed-ability student pairs. The study examined the effects of interaction cues and ability grouping on performance, time, en route behavior, and attitudes toward the instruction.

Results for performance indicated that students who used the cued version of the program performed significantly better on the posttest than students who used the noncued version. In addition to better posttest performance, students using the cued version of the program also performed significantly better on the practice items than students using the noncued version of the program.

There are several possible explanations for why students who used the cued version performed better than those who used the noncued version. These explanations are related to how the dyads progressed through the different versions of the program. Direct observation of student interaction revealed that dyads who used the cued version of the program exhibited more summarizing behavior than dyads who used the noncued version. Cued dyads also spent significantly more time on the interaction screens than the noncued dyads. It is likely that summarizing the content increased learning for students who used the cued version of the program.

Other researchers have demonstrated the beneficial effects of summarizing within cooperative learning groups. Yager et al. (1985) determined that students in cooperative dyads who were directed to either summarize information or evaluate their partner's oral summaries performed significantly better than cooperative dyads given little or no direction to summarize. Similarly, McDonald et al. (1985) found that members of cooperative dyads trained to read text passages and summarize information for their partners recalled more information than members of cooperative dyads not given summarization training. Similar results for summarizing were obtained in other cooperative learning studies (Lambiotte et al., 1987; O'Donnell, Rocklin et al., 1987).

Because students who used the cued version did summarize information before answering practice problems, it is not surprising that these students learned more from the program than students who used the noncued version. Summarizing information presented in an instructional program is one of the effective elements of instruction (Gagné, 1985; Hunter, 1982). Although all students in this study were instructed to summarize when needed, the cues provided the direction and reminders necessary for consistent interaction between group members.

Dyads who used the cued version of the program also exhibited significantly more helping behaviors (asking for help, giving help, checking for understanding, giving encouragement) than those who used the noncued version. These additional helping behaviors may have had a positive influence on the performance of students who used the cued version. It has been demonstrated that interactions such as these contribute to more effective learning within cooperative groups. Based on the results of many small-group learning studies, Webb (1989) has determined that the amount of help given or received by members of cooperative groups correlates positively with gains in achievement. King (1989) reported that students in dyads that asked task-related questions and discussed problem-solving strategies achieved more than students who did not exhibit these interaction behaviors. The observation data collected from a sample of dyads in the current study categorized as asking and giving help interaction behaviors such as "asking task-related questions" and "discussing problem solving strategies." Consequently, dyads using the cued version of the program did, in fact, exhibit more constructive group-member interactions like those identified by Webb (1989) and King (1989) than did dyads using the noncued version.

Examining posttest performance by ability across versions yielded few surprises. Students assigned to higher-ability dyads performed significantly better on the posttest than students assigned to mixed-ability dyads. Both these groups performed significantly better on the posttest than did students assigned to the lower-ability dyads. Perhaps the most noteworthy finding dealing with ability grouping was the lack of any significant difference in posttest performance between homogeneously and heterogeneously-grouped lower- and higher-ability students. Apparently neither the higher-ability nor lower-ability students were penalized by being paired with lower-ability students. These results may lend some support for cooperative learning practitioners who advocate heterogeneous grouping. However, these results also indicate that the lower-ability students learned the same amount from the program whether they were paired with a higher-ability partner or another lower-ability partner. This evidence does not support claims that heterogeneous grouping is more beneficial for lower-ability students in terms of learning the information and skills presented in an instructional program.

The results from a number of en route measures examined by ability grouping create an interesting picture of the learning behaviors of students assigned to the different ability groups. Students in the lower-ability dyads performed significantly worse on the practice items than students in either the mixed-ability dyads or higher-ability dyads. It appears that having a higher-ability student in the group increased practice performance, regardless of whether the higher-ability student was paired with a lower- or higher-ability student. This may indicate that the higher-ability students in the mixed-ability dyads were more responsible for answering the practice problems than their lower-ability partners. This idea is supported by the fact that lower-ability students performed the same on the posttest whether they were paired with a higher-ability student or not. The time data for the three different ability groups also indicate some typical learning behavior patterns. The higher-ability dyads spent significantly less time on the instruction screens than did either the heterogeneous groups or the homogeneous lower-ability groups. This was probably due to the reading levels of the higher-ability students. These students most likely read the information presented during the information screens more quickly than did the lower-ability students. Although students in higher-ability dyads spent less time on the information screens than did students in the other dyads, they spent significantly more time on the practice screens. This suggests students in the higher-ability dyads discussed the practice items more thoroughly than students in mixed or lower-ability dyads before selecting answers.

Differences in the amount of off-task behavior between students in the different ability groupings shed additional light on why students from some groups learned more than students from other groups. Students in the lower-ability and mixed-ability dyads were off-task more than the higher-ability dyads. The presence of a lower-ability student increased the chances of one or both dyad members being off-task. Whether being off-task is influenced by ability, or ability is influenced by the propensity for being off-task is not certain. What is certain is that assignment to different ability groupings influenced off-task behavior in the current study.

There were a few attitude differences attributed to ability grouping. Students in the higher-ability dyads were more confident about performing well on the posttest than students in the other types of dyads. This is not surprising, considering they did very well on the practice items. It is interesting to note, however, that not all higher-ability students in this study responded with higher levels of confidence. When all higher-ability students' responses to the confidence survey item were analyzed by type of grouping, those higher-ability students grouped homogeneously responded with significantly higher levels of confidence than those higher-ability students paired with lower-ability students.

Although the heterogeneous dyads answered nearly the same number of practice items correctly as the higher-ability dyads, the higher-ability students in the heterogeneous dyads were less confident about doing well on the posttest. It is possible that watching a lower-ability partner struggle with the material shook the confidence of the higher-ability partner. It is also possible that the higher-ability partners did not feel comfortable with any help or feedback they received or needed to receive throughout the program. In any case, these results lend some support to those studies that have demonstrated more favorable results for homogeneous rather than heterogeneous dyads (Hooper, 1992, Hooper & Hannafin, 1988, 1991).

The only attitude item that may have been significantly affected by version was the statement, "I would like to learn more about designing controlled experiments." Although the analysis for this individual item followed a nonsignificant overall attitude difference by version, students who used the cued version of the program did answer more favorably than students who used the noncued version. Perhaps the increase in peer interaction as well as higher levels of achievement prompted the students in the cued version to exhibit a higher level of continuing motivation in regard to the content of the program. This might be explained by the idea that continuing motivation is influenced by such factors as emotional or affective responses to learning situations as well as the type and degree of social rewards (Keller, 1987; Maehr, 1976).

The results from this study support previous research on the effects of providing cues in non-CBI cooperative learning programs (Lambiotte et al., 1987; O'Donnell, Dansereau et al., 1987; O'Donnell, Rocklin et al., 1987; Yager et al., 1985). These results also lend support to models of cooperative learning that suggest the type and amount of interaction between group members is an important factor to influence learning (Johnson et al, 1990; Sharan & Sharan, 1976; Slavin, 1980).

The present results also have implications for the design of computer-based instruction. Since many teachers group students at computers, designers should consider including cues to stimulate constructive peer interaction throughout an instructional program. Others have demonstrated that students may not routinely summarize and share explanations in small groups if they are only instructed to do so at the beginning of a lesson. After reviewing the research literature on small group learning, Cohen (1992) indicated that students in small groups tend to operate at the lowest levels of interpersonal skill unless they are directed to do otherwise. This is echoed by cooperative learning theorists who suggest that strategies should be designed to facilitate constructive interaction behavior (Johnson et al., 1990; Slavin, 1983). This study shows that interaction cues can be designed to facilitate such constructive behavior when students work together during a CBI lesson.

Several specific areas for future research are suggested. Although the cues differentially affected the number of times students summarized, students in both the cued and noncued versions interacted approximately the same number of times during the explanation screens. These explanation screens offered more specific direction to the students by asking questions to be answered. Perhaps a more directed approach to the summary screens through the use of questioning strategies would have yielded higher participation during these screens. Also, the cues used in this study called on students by name. It is not certain how this small amount of personalization may have influenced the students' experience with the program. Future research could investigate the effects of personalization within cooperative learning groups.

There may also be some value in investigating the effects of summary and explanatory cues for individuals versus groups. The effects of structuring verbal interaction may become even clearer if groups are compared to individuals who are prompted to summarize and explain to themselves throughout an instructional program. It may also be beneficial to redesign the computer program to accommodate more explicit requirements for individual participation, whether students are placed in groups or work by themselves. A weakness determined in this study was the limited individual participation within the program itself. Future research designed to minimize this problem may include having individual students within dyads complete each practice item separately. This type of program design might yield results that paint a more intimate picture of group member involvement. Research dealing with many of the design issues illuminated in this study may help determine the best possible way to develop CBI programs for individuals as well as cooperative learning groups. □

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