DOCUMENT RESUME

ED 362 205 IR 016 361

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TITLE The Effects of Learner Control and Group Composition in Computer-Based Cooperative Learning.
PUB DATE Jan 93
NOTE 39p.; In: Proceedings of Selected Research and Development Presentations at the Convention of the Association for Educational Communications and Technology Sponsored by the Research and Theory Division (15th, New Orleans, Louisiana, January 13-17, 1993); see IR 016 300.
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Academic Achievement; *Aptitude; Comparative Analysis; *Computer Assisted Instruction; *Cooperative Learning; Elementary School Science; Elementary School Students; Heterogeneous Grouping; Homogeneous Grouping; *Instructional Effectiveness; Intermediate Grades; *Learner Controlled Instruction; Pretests Posttests; *Programed Instruction; Retention (Psychology); Student Attitudes; Tables (Data); Time Factors (Learning)

ABSTRACT

This study examined the effects of instructional control and aptitude composition on performance, interaction, and attitudes during a computer-based cooperative science lesson. A sample of 152 fifth and sixth grade students completed the instruction either under the learner control (LC) or the program control (PC) treatment. In the LC treatment, students exercised control over the amount, review, and sequence of instruction. Students in the PC treatment followed a predetermined instructional path. At the end of the lesson, all students completed a posttest and an attitude questionnaire. They also indicated their confidence by predicting the score on the posttest. An identical test was administered two weeks later for measuring retention. Time for each group and interaction in representative groups were also recorded. Results suggested that both heterogeneous grouping and learner control had significant effect on learning, time on task, verbal interaction, and attitudes. Working in heterogeneous groups increased confidence more than working in homogeneous groups. High-ability students outperformed low-ability students on all dependent variables, except attitudes. The implications for designing microcomputer software and future research are discussed. Statistical tables showing means and standard deviations for scores of achievement, confidence, retention, attitude, instructional time, and verbal interaction are appended. (Contains 46 references.) (Author/KRN)

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Abstract

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The Effects of Learner Control and Group Composition in Computer-Based Cooperative Learning

It is often argued that microcomputers are capable of delivering effective instruction by adjusting the content to cognitive and affective needs of each student. This capability had considerable effects on instructional designers by encouraging, in some cases forcing, them to develop learning materials which are sensitive to individual differences of students. Efforts toward integrating the power of computers with the popularity of individualized instruction have long dominated the educational software market.

The evidence from research shows that individualized instruction may be effective under certain conditions. Using familiar contexts for learning consistently yielded better performance and attitudes (Ross & Morrison, 1989). Adapting the lesson sequence or the difficulty of practice items to individual differences promoted higher student achievement (Tennyson, 1981). Tailoring the instruction to progress and needs of each student resulted in better learning efficiency (Wang & Walberg, 1983).

However, there is also evidence showing that individualized instruction may not always be desirable. Although educators in public schools often assume that computer-based instruction must incorporate an individualistic paradigm of learning, researchers have raised serious questions regarding the effectiveness of individualized instruction (Hooper, 1992; Johnson & Johnson, 1986; Mevarech, Stern, Levita, 1987).

It appears that even the most successful form of individualized instruction may have some problems. First, the high cost and complexity of designing adaptive instruction that caters to a wide variety of learning needs may impose severe limitations on the potential for delivering individualized instruction. Practical constraints become particularly challenging when students need separate workstations for completing instruction (Hooper & Hannafin, 1991). Second, individualized instruction may reduce student experiences to the resources provided only by the learning environment. This approach denies the benefits of peer interaction which can be highly useful in many learning situations such as those involving prosocial behavior, group-to-individual transfer, and creative skills (King, 1989; Webb, 1982). Finally, working alone for extended periods may create isolated situations in which students are bored, anxious, and frustrated. These feelings may have deteriorating effects on students' achievement motivation (Johnson & Johnson, 1986).

The limitations of individualized instruction have forced educators to develop more effective strategies. Cooperative learning has been suggested as a powerful alternative to individualized instruction (Johnson & Johnson, 1989; Kagan, 1992; Sharan, 1980; Slavin, 1983). However, there are a number of cooperative learning methods. What characterizes these methods is that students work together in small groups to accomplish a common goal. Such a collaboration usually involves positive interdependence promoting mutuality among students, individual accountability as a measure of personal responsibility, peer interaction generating instructional support, social skills necessary for working effectively with others, and group processing as a way of improving team performance.

A large body of research suggests that cooperative learning methods may be more effective than competitive and individualistic experiences in promoting desired educational outcomes. For example, a meta-analysis that examined 226 studies comparing the impact of cooperative and individual structures on student performance yielded an average effect size of .63 in favor of cooperation. Similar results were reported for the comparison of cooperative and competitive methods (Johnson & Johnson, 1989). Most of these studies, however, were conducted in regular classrooms with limited use of emerging interactive technologies such as computers and videodiscs. The effectiveness of technology-based cooperative learning environments have been examined only in recent years. The results from several integrative reviews suggested that cooperative learning which incorporated new technologies improved both cognitive and affective outcomes (Rysavy & Sales, 1991; Webb, 1988).

Although it is not known what exactly mediates the effectiveness of cooperative learning, group composition is frequently mentioned as a potential factor producing better achievement and attitudes. Cooperative learning usually involves heterogeneous grouping; that is, groups are formed to include students from discrepant aptitudes, gender, social status, and ethnic backgrounds. Despite this common use, researchers are not in complete agreement on the efficacy of heterogeneous grouping.

Supporters of heterogeneous grouping claim that all students benefit from working with partners of different abilities. It is argued that high ability members of the group may take an active role in providing support and guidance to their low ability partners. These activities often involve the use of generative strategies that makes the learning experience more meaningful (Wittrock, 1990). Heterogeneous grouping may also provide beneficial opportunities for low ability students. As a consequence of receiving personalized help and academic support from more able partners in the group, low ability students may improve their personal expectations for competence and invest more effort toward accomplishing the group goal (Cohen, Lotan, Catanzarite, 1990). A number of studies demonstrated that all students benefited from working in heterogeneous groups compared to working alone (Dalton, Hannafin, & Hooper, 1989; Gabbert, Johnson, & Johnson, 1986; Hooper, 1992; Johnson, Skon, & Johnson, 1980; Simsek & Hooper, 1992; Yager, Johnson, Johnson, & Snider, 1986). There is also evidence showing that heterogeneous grouping, compared to homogeneous one, is particularly effective for less able students while it is not detrimental for their high ability partners (Hooper & Hannafin, 1991; Simsek & Tsai, 1992).

Critics of heterogeneous grouping claim that it promotes personal gains for some students at the expense of others, but these researchers are divided as to who benefits most from heterogeneous group work. After reviewing some studies, Hill (1982) concluded that the achievement of high ability students was hindered by medium and low ability partners. Beane and Lemke (1972), on the other hand, found that heterogeneous grouping helped high ability students more than did other members of the group. Similar questions were raised for the achievement of low ability students. Slavin (1983) argued that heterogeneous grouping may offer few opportunities for low ability students when they are simply given the correct answers without explaining the solution process behind answers. Peterson and Janicki (1979) supported that high ability students performed better and had more positive attitudes in small groups, whereas low ability students gained more from traditional whole class instruction. Goldman (1965) provided contrasting evidence indicating that students working with partners of higher abilities performed better than those working with partners of similar or lower abilities. Researchers also suggested that average students are often neglected in heterogeneous groups. Swing and Peterson (1982) found that peer interaction in mixed groups facilitated the achievement of high and low ability students, but did not affect the achievement of medium ability students. Webb (1982) reported similar findings suggesting that average students in homogeneous groups showed better achievement and received more explanations than average students in heterogeneous groups. It appears that even the critics of heterogeneous ability grouping agree on the effectiveness of cooperation in small groups, but they do not have a clear consensus as to what types of students benefit most from this experience.

The inconclusiveness of research findings on cooperative group composition forces educators to develop better intervention strategies that will enhance the performance of all students working in small groups. One strategy for providing more effective instruction is to give students an opportunity to have control over their own learning. Exercising control based upon group decisions may help students develop better metacognitive skills needed for successful learning.

The concept of learner control is intuitively appealing because students differ in aptitudes, interests, motivation, learning styles, and personality variables (Carrier, 1984). The results from a number of experimental studies suggest that there are certain situations in which exercising control is more effective than following a fixed instructional sequence. When students were allowed to adjust the familiarity of content to their own backgrounds, for example, they performed significantly better on both achievement and attitude measures (Ross, 1984). Similarly, providing students with advice about their academic performance and learning needs has been found to be more effective than imposing a fixed instructional sequence or complete learner control (Tennyson & Rothen, 1979). Researchers argue that guided learner control that is contingent upon students' ongoing performance combines the most desirable features of adaptive instructional support and personal decision making.

Studies also demonstrate that practicing control does not always promote desired educational outcomes. Given total learner control, students usually terminate the lesson prematurely or they cannot make appropriate decisions regarding the instruction they need to complete (Carrier, 1984; Kinzie, 1990; Snow, 1980; Tennyson, 1981). It has been suggested that particularly younger and less able students benefit very little from exercising control, compared to mature and more able students (Hannafin, 1984; Steinberg, 1989). An explanation for these results may be that low ability students usually lack metacognitive skills that are critical in evaluating the situation and producing effective solutions. Having failed frequently on academic tasks, these students may be more comfortable with external instructional support (Simsek & Sales, 1992).

Although there seems to be a strong agreement in the literature, only several studies examined the relationship between student ability and instructional control. Ross and Rakow (1981) conducted a study in which the number of supporting examples was adapted to pretest scores through program control, selected through learner control, kept constant, or nonadaptive content was presented through traditional lecture. Results demonstrated that program control of instructional support promoted highest mathematics achievement on both immediate and delayed posttests while learner control resulted in lowest achievement. Nonadaptive support and traditional lecture treatments produced medium-range outcomes. The results also suggested that program control was more effective for low ability students. Fry (1972) found similar findings indicating that high ability students learned significantly more under a high degree of learner control. Gay (1986) reported that students with higher prior knowledge performed equally well under both program control and learner control treatments, but students with low prior understanding scored less under learner control as a result of poor sequencing decisions. It is important to note that all of these studies were conducted in college environments with relatively mature participants. Results appear to be different with younger students. For example, Klein and Keller (1990) found that type of instructional control did not affect performance and confidence of seventh grade students, whereas ability and locus of control improved the same outcomes. More research needs to be conducted in elementary classrooms for obtaining conclusive results.

It is also true that most of the conclusions about learner control have been derived from studies on individualized instruction. The effects of exercising learner control in cooperative groups are not known yet. It is crucial for instructional designers to recognize that research findings from individualized instruction may not necessarily be generalizable to small group learning. When high ability students dominate the group, for example, low ability students may suffer from completing too little or difficult instruction. When less able students dominate, on the other hand, more able students may suffer from completing too much instruction or being bored (Simsek & Hooper, 1992).

The basic question still remains: What will be the effects of exercising control on performance, interaction, and attitudes of students working together in homogeneous and heterogeneous ability groups during a computer-based cooperative science lesson? Further research is needed to answer this question. The purpose of the present study is to extend research findings by determining whether exercising control over the amount, sequence, and review of instruction in cooperative groups would be more effective than following a fixed instructional path.

Method

Subjects

A sample of 152 fifth and sixth grade students from a suburban school district in Minnesota participated in the study. Of this total number, 84 (55%) were fifth graders and 68 (45%) were sixth graders. The gender distribution was 73 (48%) males and 79 (52%) females. The sample comprised primarily of middle-class, Anglo-American students with a small percentage of other ethnic backgrounds. Approximately equal number of subjects were randomly assigned to treatment conditions.

Materials

Lesson Content. Students completed a tutorial lesson on solar energy. The CBI lesson was originally developed by Kinzie, Sullivan, and Berdel (1988) for individualized instruction. Modified versions of the lesson for both individuals and cooperative groups were prepared and validated in another study (Simsek & Sales, 1992). Based upon the results of these studies and according to design principles described by Dick and Carey (1985), a formative evaluation procedure was conducted. Final version of the computer lesson contained five major segments: (a) solar power; (b) active solar heating; (c) passive solar heating; (d) solar cells; (e) future of solar energy. In addition to these instructional segments, the lesson included an introduction explaining the rules of cooperation and a closing with comments about the performance of students. Relative to the control strategy embedded in the lesson, students received instruction that varied by amount, review, and sequence.

Ability Test. Students were classified as high and low ability according to their performance on the Iowa Test of Basic Skills. Students with combined scores at or above the 60th percentile were defined as high ability, while low ability students were defined as those with the combined scores at or below the 40th percentile. As a way of reducing the classification error, students with combined scores between the 60th and 40th percentiles were not included in the study. The KR-20 reliability for this standardized ability test for both 5th and 6th grade students was .91.

Posttest. Students completed an individual posttest both at the end of the instruction and approximately two weeks after the instruction. The test included 40 multiple-choice questions. Half of the questions consisted of recall items whereas the other half contained comprehension items. The KR-20 reliability for this posttest was .83 with an average item difficulty of .67. A typical recall item on the test was: "What is the basic source of energy that all living creatures use? (a) Sunshine; (b) Electricity; (c) Gasoline; (d) Fossil fuels". A typical comprehension item was: "Which of the following is more likely in the twenty-first century? (a) Fossil fuels will no longer be used; (b) Solar energy will be the alternative to nuclear power; (c) Most of the old buildings will be using passive solar heating; (d) Water will be the main source of energy".

Attitude Questionnaire. Following the immediate posttest, students responded to a Likert-type questionnaire. This instrument contained 30 items, divided equally among the categories of attitudes toward the delivery system, subject matter, and team work. Possible responses ranged from "Strongly Agree (5)" to "Strongly Disagree (1)". The Cronbach's Coefficient Alpha reliability for the questionnaire was .91. A typical item for each category was: "I enjoyed working with the computer" (delivery system); "I would like to learn more about solar energy" (subject matter); and "I feel more comfortable working in a small group than working alone" (team work).

Interaction Scale. Peer interaction in twenty representative groups was videotaped and analyzed according to categories of the Interaction Scale. This scale contained ten categories: (a) reading information; (b) asking questions; (c) giving answers; (d) seeking clarification; (e) providing explanations; (f) making comments; (g) energizing the group; (h) suggesting directions; (i) entering group response; (j) demonstrating off-task behavior. The coding of peer interaction in groups was performed by two well-trained observers who had expertise on cooperative learning and computer-based instruction. Several videotapes were coded by both observers for calculating reliability. Analysis of group interaction also included qualitative data regarding the nature and degree of student discourse.

Training Observers

Two observers were trained about analyzing interaction in small groups. Training comprised of several stages. First, the experimental procedures were explained and each of the categories in the Interaction Scale was discussed. Second, the observers watched a videotape that showed two students working together on the same computer. This activity allowed the observers to pay close attention to behaviors involving group work and discuss them in detail. Third, the observers coded peer interaction in a sample group by using the Interaction Scale described above. Finally, independent codings of the two observers were compared. The percentage of agreements between the observers was .98.

Cooperative Skills Training

Students in the participating school had been trained extensively about collaborative skills. Cooperative learning is considered to be an integral part of the school curriculum. In addition to previous training, all possible subjects attended a one-hour training program designed specifically for them. The main purpose behind this activity was to encourage students to employ specific strategies involved in this study. Participants completed several exercises emphasizing the basic principles of cooperative learning.

The first exercise, called "Magic Triangle" (Johnson, Johnson, & Holubec, 1991), required students to find the maximum number of embedded triangles in a big one. Half of the participants completed this exercise in cooperative groups, while the other half worked alone. The result was overwhelmingly better success rate for those working in groups. Therefore, successful students shared their answers with all participants and explained the strategies they employed. This helped students to draw the conclusion that working with others can be more effective and enjoyable than working individually. Following this activity, the discussion focused on specific behaviors which were helpful (i.e. explaining) and not helpful (i.e. teasing) for group success.

Second, the "Broken Circles" exercise (Cohen, 1986) emphasized the importance of positive interdependence among members of a cooperative group. Each group was given pieces of broken circles. The task was to form at least one complete circle for each member. Once everyone in the group had a complete circle, members were to shuffle their pieces and form new circles. They had to exchange the pieces voluntarily without being asked for. Students were also instructed not to talk and take others' pieces unless offered. This game encouraged students to share their resources in accomplishing the mutual goal.

The third exercise, called "Contractions and Punctuations" (Johnson, Johnson, & Holubec, 1991), was about correcting grammar errors in a letter. It provided students with opportunities to practice cooperative skills on a school-related task. After this activity and presentations of several students demonstrating correct answers, participants were asked to discuss how well their group did as a team and list three advantages and disadvantages of working together with others in a small group.

Procedures

Based upon their combined scores on a standardized ability test, students were randomly assigned to homogeneous and heterogeneous groups. A homogeneous group included two students of the same ability, while a heterogeneous group included one high and one low ability student. Prior to the experiment, all students who obtained parental consent participated in the training program.

Students completed the instruction in three consecutive days, approximately thirty minutes a day. To secure confidentiality, each subject was assigned a code number. They were also given a card showing their computer number. During the first day, students completed two instructional segments. At the end of the daily session, they discussed how well their group did and listed two behaviors that were helpful and not helpful for their success. They also specified a behavior which they promised to improve for the next day. Students began the second day by discussing the important rules of cooperation as well as the information they learned from the first day. Then, they studied two additional segments of the lesson. The second day ended with similar group processing activities. Students completed the last instructional segment in the third day. Following a brief wrap-up time, the immediate posttest and attitude questionnaire were administered. Two weeks later, an identical posttest was given to measure retention.

Treatments

During the instruction, students completed either the learner control or program control version of the computer lesson. Each instructional treatment varied by the type and degree of control provided. Major differences between the two versions of the lesson are described below.

Learner Control. This treatment allowed students to exercise control over the amount, review, and sequence of instruction. Following the introduction, group members selected a segment from the main menu. They had complete control over the segment they wanted to start with. After reading and discussing the information in each lesson segment, students responded to embedded questions. They had an option of deciding the number of practice items they wanted to see. Before they answered any question, the computer told them how many items (ranging from 4 to 7) were available in that particular segment. The whole lesson contained total of 25 practice items. Because this was a cooperative lesson, group members had to carefully examine the options and reach a consensus before entering a response.

Based on their answer, students received immediate feedback. When the response was correct, affirmative feedback with a statement saying "That's correct!" was presented. When their response was incorrect, however, students were presented a statement saying "Sorry. That's incorrect. Would you like to review the material before you answer the question one more time?" Then, group members either reviewed the relevant segment or responded to the same question again. Review screens contained shorter information than original screens of the tutorial. Following the third incorrect response, the correct answer with a brief explanation saying like "The correct answer is (a) because all living creatures need sunlight to grow" was displayed. After each segment, the main menu was presented. Students decided to study another segment or terminate the lesson. Once they selected a segment, they could not exit until the practice items. At the end of the instruction, students received an evaluative comment about their overall performance.

Program Control. This treatment did not allow students to exercise control. All students completing this version of the lesson received identical instruction. Students did not make fundamental decisions or choices about the instructional sequence. They simply read the infcrmation and answered all embedded questions. Similar to the learner control treatment, students had to carefully examine the options and reach a group consensus about their response.

When the answer to a question was correct, students received affirmative feedback saying "That's correct!" and proceeded to the next question. When incorrect, on the other hand, a review of the relevant segment was automatically presented following a statement saying "That's incorrect. Let's review the material before you answer the question again". Then, students responded to the question one more time. After three incorrect responses, the correct answer with a brief explanation was presented. Upon completion of all lesson segments, students received an evaluative comment about their overall performance.

Design and Data Analysis

The study employed a 2 X 2 X 2 randomized block design. The first factor was Grouping (homogeneous, heterogeneous), the second Ability (high, low), and the third Control (learner, program). Dependent variables were achievement, confidence, retention, attitudes, time on task, and interaction. In analyzing research data, three-way ANOVA and Scheffe's multiple comparisons test were used. The alpha level for testing differences was set as .05, unless otherwise indicated.

Results

Achievement

The first dependent variable of the study was student achievement. This variable was operationalized as the individual score on the immediate posttest. Means and standard deviations for achievement scores are given in Table 1. The mean score for heterogeneous groups (M=28.37) was higher than the mean score for homogeneous groups (M=25.39). High ability students had a greater mean score than low ability students (M=29.73 and M=24.01, respectively). The mean achievement score for students who worked under the learner control treatment (M=27.73) was higher than the mean achievement score for those working under program control (M=25.99).

Insert Table 1 About Here

Three-way ANOVA results demonstrated that heterogeneous grouping significantly improved achievement compared to homogeneous grouping [$F(1,144) = 10.85$, $p<.001$]. High ability students outscored low ability students [$F(1,144) = 41.78$, $p<.001$]. Groups working under learner control performed better than those working under program control [$F(1,144) = 4.71$, $p<.032$]. Two-way interaction effect between Grouping and Ability was significant [$F(1,144) = 4.85$, $p<.029$]. The Scheffe procedure indicated that homogeneous low ability groups showed the lowest achievement compared to homogeneous high ability groups ($p<.001$) as well as both high ($p<.001$) and low ability students working together in heterogeneous groups ($p<.002$). The difference between the achievements high and low ability members of heterogeneous groups also showed significance ($p<.035$). None of the other comparisons were significant.

We also examined the effects of independent variables on recall and comprehension items separately. Results regarding comprehension items suggested similarity with the results for overall test scores. However, the results on recall items differed from the results on comprehension items in two important ways. First, the interaction between Grouping and Ability was not significant [$F(1,144)=1.51$, $p<.221$]. Instead, the interaction between Grouping and Control showed significance [$F(1,144)=4.30$, $p<.040$]. Secondly, three-way interaction was significant [$F(1,144)=5.18$, $p<.024$]. Further analyses indicated that the most obvious difference was between the achievements of low ability students working under learner control ($p<.001$) in homogeneous ($M=10.50$) and heterogeneous cooperative groups ($M=14.94$), suggesting the effectiveness of heterogeneity.

<u>Confidence</u>

The concept of confidence in this study was defined as the perceived likelihood of personal success (Keller, 1983). Upon completion of the immediate posttest, students were asked to predict their achievement score and write it down to the first page of the test. Means and standard deviations for confidence scores are presented in Table 2. Students in heterogeneous groups had higher scores than those in homogeneous groups (M=31.50 and M=28.08, respectively). High ability students (M=31.20) reported greater confidence than low ability students (M=28.33). The mean confidence score for students exercising control over the lesson was slightly higher than the mean score for those following a predetermined instructional path (M=30.07 and M=29.44, respectively).

Insert Table 2 About Here

Three-way ANOVA results yielded significant main effects for both Grouping [$F(1,144)=12.58$, $p<.001$] and Ability [$F(1,144)= 9.05$, $p<.003$]. Heterogeneous groups and high ability students outscored homogeneous groups and low ability students. Neither the main effect for Control [$F(1,144) =0.52$, $p<.470$] nor the interactions were significant.

Retention

In order to measure retention, an identical posttest was administered two weeks after the instruction. Data from 145 students were included in the analysis since 7 students were absent during the retention test. The correlation between scores on the immediate and the retention posttests was .73. Means and standard deviations for retention scores are contained in Table 3. Students in heterogeneous groups (M=26.51) had higher retention scores than those in homogeneous groups (M=24.16). The mean score for high ability students was higher than the mean score for low ability students ((M=28.44 and M=22.18, respectively). Students working under learner control (M=26.47) had higher retention scores than those working under program control (M=24.01).

Insert Table 3 About Here

Three-way ANOVA results demonstrated that heterogeneous groups retained more information than homogeneous groups [$F(1,137)=5.07$, $p<.026$]. High ability students consistently outperformed low ability students on the retention posttest [$F(1,137)=40.65$, $p<.001$]. Exercising learner control was more effective for retention than following a fixed instructional sequence [$F(1,137)=6.79$, $p<.010$]. None of the interactions was significant.

Attitudes

Another dependent variable was attitudes toward the delivery system (CBI), subject matter (science), and group work (pairs). Means and standard deviations for total attitude scores are included in Table 4. Students in heterogeneous groups had a higher mean score than those in homogeneous groups (M=119.95 and M=113.49, respectively). The mean score for low ability students (M=117.56) was greater than the mean score for high ability students (M=115.68). Students working under learner control had a higher mean attitude score than those working under program control (M=120.19 and M=113.26, respectively).

Insert Table 4 About Here

Three-way ANOVA results suggested the effectiveness of heterogeneous groups because the main effect for Grouping was significant [$F(1,144)=5.70$, $p<.018$]. Although there was a difference in the attitudes of high and low ability students, the main effect for Ability was not significant [$F(1,144)=0.57$, $p<.452$]. The main effect for Control was significant [$F(1,144)=6.89$, $p<.010$] in favor of learner control. Among interactions, only the interaction between Grouping and Ability was significant [$F(1,144)=5.00$, $p<.027$]. The Scheffe procedure indicated a statistically significant difference between the attitudes of low ability students in homogeneous and heterogeneous groups ($p<.015$).

We also checked the significance of results according to categories of the attitude questionnaire. On the subscale for attitudes toward computer-based instruction, only the main effect for Grouping [$F(1,144)=5.49$, $p<.020$] and interaction between Grouping and

Ability were statistically significant [$F(1,144)=4.09$, $p<.045$]. The Scheffe procedure showed significance between the attitudes of low ability students in homogeneous and heterogeneous groups favoring heterogeneity ($p<.025$). No comparison was statistically significant on the subscale for attitudes toward science. On the subcategory for attitudes toward group work, the main affect for Grouping was significant [$F(1,144)=4.27$, $p<.041$]. This suggested that students in heterogeneous groups developed more positive attitudes toward group work. The main effect for Ability was not statistically significant [$F(1,144)=0.24$, $p<.627$]. Learner control promoted better attitudes toward working with others in groups than program control [$F(1,144)=14.17$, $p<.001$]. Two-way interaction between Grouping and Ability was the only significant interaction effect [$F(1,144)=6.78$, $p<.010$]. The Scheffe procedure showed significant differences between the attitudes of low ability students in homogeneous and heterogeneous learning groups ($p<.010$) favoring heterogeneity. No other comparison was statistically significant.

Time on Task

Amount of time for each cooperative group was recorded during the instruction. The means and standard deviations for time on task are mentioned in Table 5. The average time for homogeneous groups (M=62.46) was longer than average time for heterogeneous groups (M=57.89). High ability students (M=58.88) spent less instructional time than low ability students (M=61.56). The completion time was shorter for students who exercised control (M=57.32) than those who followed a predetermined instructional path (M=63.00).

Insert Table 5 About Here

Three-way ANOVA results indicated that homogeneous groups used significantly longer time than heterogeneous groups [$F(1,144)=14.27$, $p<.001$]. High ability students spent less time on task than low ability students [$F(1,144)=4.68$, $p<.032$]. Program control required more time to complete the lesson than learner control [$F(1,144)=22.60$, p<.001]. Two-way interaction effect between Grouping and Ability was also significant [$F(1,144)=4.68$, $p<.032$]. The Scheffe procedure suggested efficiency for homogeneous high ability groups ($p<.025$) and students in heterogeneous teams compared to low ability students in homogeneous groups. No other comparison suggested statistically significant differences regarding time on task.

Interaction

Peer interaction in groups was coded according to ten categories of the Interaction Scale, but only eight of these categories were related to verbal interaction among students. The other two categories were "entering group response" and "demonstrating off-task behavior". They were excluded from comparisons of the treatment groups because these behaviors sometimes did not involve peer interaction or group behavior that were directed to completion of the task. The means and standard deviations for total verbal interaction are reported in Table 6. The mean score for heterogeneous groups (M=132.31) was higher than the mean score for homogeneous groups (M=100.17). High ability students averaged a greater verbal interaction score than low ability students (M=134.60 and M=91.45, respectively). The mean score for students working under the learner control treatment (M=132.30) was higher than the mean score for those working under the program control condition (M=93.75).

Insert Table 6 About Here

Three-way ANOVA yielded a significant main effect in favor of heterogeneous grouping [$F(1,32)=4.44$, $p<.043$]. The difference between the interaction means of high and low ability students was significant [$F(1,32)=6.70$, $p<.014$]. Students working under learner control engaged in more verbal interaction than those working under the program control treatment [$F(1,32)=5.46$, $p<.026$]. None of the interaction effects was statistically significant. We also checked the predictability of student achievement based on interaction categories. The means, standard deviations, and correlations of interaction categories with achievement are presented in Table 7.

Insert Table 7 About Here

It appears that only three categories of peer interaction can successfully predict student achievement. Those are seeking clarifications from the partner ($r=.315$, $p<.047$), providing explanations after giving an answer ($r=483$, $p<.002$), and demonstrating off-task behavior during the group work ($r=-445$, $p<.004$). It should be noted, however, that the correlation between off-task behaviors and student achievement was a negative one. When total verbal interaction scores are used to predict achievement on the posttest, the correlation was positive and significant ($r=349$, $p<.027$).

Discussion

This study investigated the effects of exercising control over the amount, review, and sequence of instruction in mixed and uniform ability groups during a computer-based cooperative lesson on solar energy. Dependent variables included achievement, confidence, retention, attitudes, time on task, and interaction.

Students in heterogeneous cooperative groups outperformed their counterparts in homogeneous groups. The achievement differences were particularly noticeable when low ability students in homogeneous groups were compared with others including low ability members of heterogeneous teams. It appears that interaction among students of discrepant abilities provides beneficial opportunities for low ability students, and it is not detrimental for the achievement of high ability students. This result is consistent with the established findings of research on cooperative group composition (Hooper & Hannafin, 1991; Simsek & Tsai, 1992). A possible interpretation of this result is that low ability students receive peer encouragement and personalized support from their more able partners. They perceive that their contributions are expected and valued for success of the group. Their partners are available to help them when they need a customized explanation for finding the answer or figuring out the solution process. When they have an incorrect idea, more able students in the group can explain why that answer is not acceptable. When the group contains all low ability students, on the other hand, members usually share the mistakes. After getting the feedback from the computer, they realize that their response is not an acceptable one. They try to enter another response without developing an alternative solution proposal because low ability students are usually unable to do so. By continuing this simple tryout pattern, group members start loosing their motivation and the perception that their partner is able to help or offer different views.

Ability was an important factor in achievement. High ability students performed significantly better than low ability students. Based on a large body of research, this is not a surprising result (Johnson & Johnson, 1989). The critical point is that high ability members of cooperative groups are usually more active in group discussions contributing toward their own success and the success of their partners. These students also perform a leadership role in heterogeneous groups by providing personalized explanations and clear directions to their low ability groupmates. All these activities involve deeper information processing and metacognitive skills including generative activities which seem to contribute to the achievement of more able students.

Students working under learner control outperformed their counterparts working under program control. This result is somewhat contrary to the conclusions derived from studies on individualized instruction because there is a tendency in the literature suggesting that elementary students cannot make appropriate decisions about their own learning needs (Carrier, 1984; Hannafin, 1984; Steinberg, 1989). It seems reasonable to expect that when students do not have metacognitive skills necessary for effective decision making, they will not be able to benefit from exercising control compared to following a fixed instructional sequence embedded in the computer lesson. However, the present study suggested that this explanation may not be applicable to cooperative learning since group members usually discuss the options carefully before making a decision or choice. When the lesson requires a group consensus about each response, many mistakes can be avoided as a consequence of getting another opinion. This is not to say that all students will be good decision makers in cooperative groups. A careful attention should be given to heterogeneity of the group and mastery contingencies for all students. Providing learner control option can be harmful or ineffective for the achievement of low ability students working in homogeneous groups. The results of this study concerning performance on recall items suggested that low ability students in homogeneous groups did not benefit from practicing control. Each decision was a challenge for these students. However, it was not the case for low ability students in heterogeneous groups because each decision served as an opportunity generating further discussion and learning from partners. It was suggested that such a situation may motivate group members to engage in more discussion that results in providing elaborative feedback (Carrier & Sales, 1987).

Results of the study suggested that heterogeneous grouping significantly improved student confidence about performance on the posttest. Also, high ability students were more confident than low ability students. However, exercising control over the instruction did not affect confidence. These results provide partial support for the findings of several other studies suggesting that student ability and cooperation in heterogeneous small groups increase confidence, while type of instructional control does not have a significant influence on the outcomes (Klein & Keller, 1990; Simsek & Sales, 1992). It may be that low ability students cooperating with equals in homogeneous groups do not have confidence either in themselves or their partners. Similarly, high ability students in homogeneous groups may lack the opportunity for comparing themselves with others because they do not receive ideas or solution proposals which are neither above nor below their own level of cognitive complexity. In heterogeneous groups, however, students can compare their performance with the performance of their partners. High ability members of the group may feel good about themselves because they know more about the task and can provide others with help to improve their performance. Low ability students in heterogeneous group may perceive that they are contributing toward the mutual goal with the support and encouragement of more able partners. Such a perception may increase their expectations for competence and motivate them to invest more efforts directed toward group goals (Cohen, 1986). Type of instructional control may not be a strong determinant in this process characterized mostly by group dynamics rather than whether the control option is given or not.

Retention results suggested that heterogeneous grouping was more effective than homogeneous grouping to help students retain more information. A possible explanation might be that members of heterogeneous groups benefit from a variety of alternatives and explanations offered to solve a problem or answer a question. When different explanations are provided, students restructure their own rationale and enrich their cognitive reasoning. Some these strategies may help them find clever ways of remembering or comprehending facts which were the core of the learning program used in the present study. This may also explain that high ability students performed better on the retention posttest than low ability students. Learner control option along with the requirement of reaching group consensus before entering each response might have provided additional opportunities for engaging in further and elaborated discussion promoting a higher retention rate than the program control treatment.

Students in heterogeneous groups developed more positive attitudes than those in homogeneous groups. Low ability students in homogeneous groups reported the lowest attitude scores than the other treatment groups. The difference in overall attitudes was particularly obvious when low ability students in homogeneous groups were compared with their low ability counterparts in heterogeneous groups. Moreover, this positive effect in favor of heterogeneity was not due to an accompanying decrement in the attitudes of high ability students cooperating with low ability students. These findings are consistent with the results of many other research studies (Dalton, Hannafin, & Hooper, 1989; Johnson & Johnson, 1989; Sharan, 1980; Simsek & Tsai, 1992). It may be that low ability students in heterogeneous groups feel more supported and satisfied than those in other groups as a consequence of their interaction with more able partners. This may produce a friendly and motivating environment in which students like the computer and cooperative group work better, but these feelings or perceptions may not be strong enough to have direct influences on the subject matter.

Ability did not affect attitudes. Perhaps, affective outcomes as operationalized in this study cannot easily be influenced by aptitude variables. Another possibility is that attitudes toward the delivery system, subject matter, and group work are mostly situational and may not be positively correlated with student ability. Also, the interaction between Grouping and Ability in favor of low ability members of heterogeneous groups may have reduced the possibility for finding a significant main effect for ability.

Students exercising control over the lesson developed more positive attitudes than those following a predetermined instructional path. This result is supportive of the findings reported by Simsek and Sales (1992). Students exercising control over the lesson may feel that they have certain amount of freedom, choice, and flexibility in the learning process. They may also think that they are the ones making important decisions and their decisions are respected. Given an option to decide whether to receive more instruction, skip certain parts of the lesson, or terminate the instruction may create intrinsic motivation and promote more positive attitudes toward components of that particular learning environment (Carrier & Sales, 1987; Kinzie, 1990; Steinberg, 1989).

Results regarding time on task demonstrated that heterogeneous groups and learner control subjects used significantly less instructional time than homogeneous groups and program control subjects. The main effect for Ability was also significant. Analysis of the interaction between Grouping and Ability showed that low ability students in homogeneous groups consistently needed more time to complete the lesson than the other groups. These results support the efficiency of cooperative learning for less able students in heterogeneous groups (Hooper & Hannafin, 1991; Simsek & Hooper, 1992; Simsek & Tsai, 1992; Webb

& Cullian, 1983). The reason might be that students in heterogeneous groups develop higher understanding of the task and employ more effective strategies in accomplishing the mutual goals. As a consequence of interacting with more able partners, low ability students in heterogeneous groups may acquire better problem solving skills. Using more efficient strategies may save important amount of time for these students. Low ability students in homogeneous groups, however, may not benefit from diversity in generating solutions that help them avoid typical mistakes and time consumption. The efficiency of learner control may be attributed to exercising control over the amount of instruction as well as using the review option effectively.

The interaction results are in agreement with the findings of other relevant studies (Hooper, 1992; King, 1989; Webb, 1983). When peer interaction in groups was analyzed based on certain categories of interaction behaviors, providing elaborations after giving an answer was found to be a successful predictor of student achievement. Another category which seem to be a good predictor of achievement was seeking clarification after receiving an answer or explanation from the partner. The correlations between these two categories and achievement were both positive and statistically significant. The final category which had the potential to predict achievement successfully was demonstrating off-task behavior during the group work. However, the correlation between this category and achievement was a negative one. That is, any increase in off-task behavior accompanied a decrease in achievement scores on the posttest.

When the categories related to verbal interaction among students were combined and the significance of differences among treatment groups were compared, all independent variables showed significant main effects, suggesting the effectiveness of heterogeneous grouping, higher ability, and learner control. It is reasonable to expect that when students are to make selections or decisions, they engage in more interactions compared to those following a fixed sequence of instruction. It is also reasonable to assume that members of heterogeneous groups demonstrate greater exchange of ideas as a consequence of trying to convince their partners with diverse abilities. Students in homogeneous groups, however, may have more agreements than disagreements as a result of their similarities. This makes discussions or explanations unnecessary, but students benefit from explaining even in the case agreement with their partners because explanations may clarify misunderstandings as well as potential conflicts.

The results of this study have certain implications for both instructional designers and educational researchers. It appears that heterogeneous cooperative grouping is an effective, appealing, efficient alternative to individualized instruction. This kind of learning particularly benefits low ability students, and it is not detrimental for high ability students. Most of the problems associated with learner control can be overcomed when members of heterogeneous groups make the decisions together. Diversity among these students can be a motivating factor when students seek and provide explanations. It seems likely that high ability students will dominate group interaction, but a knowledgeable instructional designer can incorporate certain elements providing equal opportunities for participation of all group members. Such important features of computer-based instructional lessons may include requiring a consensus for each response, encouraging students to explain their rationales behind decisions, assigning critical roles to members, checking randomly if everyone has agreed on the choices made, giving multiple opportunities for mastery before proceeding to the next practice item or lesson segment, asking students to take turns using input devices, and providing specific instructions for effective group processing.

Further research is needed to clarify the relationship between group composition with regard to students' learning styles and academic performance. Integrating generative activities into cooperative decision making should be further investigated. The effects of various feedback strategies during cooperative group work needs to be examined. The relationship between exercising learner control and manipulating group size deserves more research attention. Qualitative studies may provide better insights than quantitative studies in analyzing peer interaction in cooperative groups.

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Table 1. Means and Standard Deviations for Achievement Scores

Ability	Type of control: Learner	Program	Total
	Homogeneous		
High			
M:	30.78	27.85	29.24
SD:	4.52	5.63	5.28
N:	18	20	38
Low			
M:	21.15	22.30	21.73
SD:	5.82	6.11	5.92
N:	20	20	40
Total			
M:	25.71	25.08	25.39
SD:	7.11	6.44	6.74
N:	38	40	78
	Heterogeneous		
High			
M:	31.28	29.26	30.24
SD:	4.94	5.45	5.24
N:	18	19	37
Low			
M:	28.44	24.63	26.49
SD:	3.71	6.25	5.46
N:	18	19	37
Total			
M:	29.86	26.95	28.37
SD:	4.54	6.24	5.64
N:	36	38	74
	Combined		
High			
M:	31.03	28.54	29.73
SD:	4.68	5.52	5.25
N:	36	39	75
Low			
M:	24.61	23.44	24.01
SD:	6.11	6.21	6.15
N:	38	39	77
Total			
M:	27.73	25.99	26.84
SD:	6.31	6.37	6.38
N:	74	78	152

Table 2. Means and Standard Deviations for Confidence Scores

	Type of control		
Ability	Learner	Program	Total
	Homogeneous		
High			
M:	30.72	28.65	29.63
SD:	4.04	5.33	4.82
N:	18	20	38
Low			
M:	26.45	26.75	26.60
SD:	8.00	7.25	7.54
N:	20	20	40
Total			
M:	28.47	27.70	28.08
SD:	6.71	6.36	6.50
N:	38	40	78
	Heterogeneous		
High			
M:	33.06	32.58	32.81
SD:	3.92	4.56	4.21
N:	18	19	37
Low			
M:	30.44	29.95	30.19
SD:	7.61	3.78	5.88
N:	18	19	37
Total			
M:	31.75	31.26	31.50
SD:	6.11	4.34	5.25
N:	36	38	74
	Combined		
High			
M:	31.89	30.56	31.20
SD:	4.10	5.30	4.77
N:	36	39	75
Low			
M:	28.34	28.31	28.33
SD:	7.97	5.97	6.99
N:	38	39	77
Total			
M:	30.07	29.44	29.74
SD:	6.59	5.72	6.15
N:	74	78	152

Table 3. Means and Standard Deviations for Retention Scores

Ability	Learner	Program	Total
	Type of control		
		Homogeneous	
High			
M:	29.94	27.22	28.08
SD:	6.84	5.56	6.20
N:	18	18	36
Low			
M:	20.75	20.50	20.63
SD:	5.46	6.45	5.90
N:	20	20	40
Total			
M:	24.63	23.68	24.16
SD:	7.35	6.87	7.08
N:	38	38	76
		Heterogeneous	
High			
M:	31.75	26.58	28.94
SD:	6.63	6.31	6.88
N:	16	19	35
Low			
M:	25.59	22.41	24.00
SD:	3.54	6.05	5.14
N:	17	17	34
Total			
M:	28.58	24.61	26.51
SD:	6.05	6.46	6.53
N:	33	36	69
		Combined	
High			
M:	30.27	26.72	28.44
SD:	6.79	5.87	6.54
N:	34	36	70
Low			
M:	22.97	21.38	22.18
SD:	5.22	6.26	5.78
N:	37	37	74
Total			
M:	26.47	24.01	25.28
SD:	7.01	6.60	6.90
N:	71	73	145

Table 4. Means and Standard Deviations for Attitude Scores

Ability	Type of control: Learner	Program	Total
		Homogeneous	
High			
M:	119.11	112.15	115.45
SD:	10.95	17.54	15.02
N:	18	20	38
Low			
M:	112.65	110.60	111.63
SD:	19.58	23.44	21.34
N:	20	20	40
Total			
M:	115.71	111.38	113.49
SD:	16.20	20.45	18.51
N:	38	40	78
		Heterogeneous	
High			
M:	120.44	111.63	115.92
SD:	10.48	15.81	14.03
N:	18	19	37
Low			
M:	129.39	118.84	123.97
SD:	11.53	17.69	15.74
N:	18	19	37
Total			
M:	124.92	115.24	119.95
SD:	11.77	16.95	15.35
N:	36	38	74
		Combined	
High			
M:	119.78	111.90	115.68
SD:	10.58	16.50	14.44
N:	36	39	75
Low			
M:	120.58	114.62	117.56
SD:	18.16	20.99	19.74
N:	38	39	77
Total			
M:	120.19	113.26	116.63
SD:	14.86	18.81	17.30
N:	74	78	152

Table 5. Means and Standard Deviations for Instructional Time

Ability		Type of control: Learner	Program	Total
		Homogeneous		
High				
	M:	58.11	61.40	59.84
	SD:	9.68	5.86	7.97
	N:	18	20	38
Low				
	M:	60.60	69.30	64.95
	SD:	8.83	5.83	8.60
	N:	20	20	40
Total				
	M:	59.42	65.35	62.46
	SD:	9.20	7.02	8.63
	N:	38	40	78
		Heterogeneous		
High				
	M:	55.11	60.53	57.89
	SD:	6.72	7.37	7.49
	N:	18	19	37
Low				
	M:	55.11	60.53	57.89
	SD:	6.72	6.72	7.49
	N:	18	19	37
Total				
	M:	55.11	60.53	57.89
	SD:	6.62	7.27	7.44
	N:	36	38	74
		Combined		
High				
	M:	56.61	60.97	58.88
	SD:	8.35	6.57	7.74
	N:	36	39	75
Low				
	M:	58.00	65.03	61.56
	SD:	8.28	7.90	8.78
	N:	38	39	77
Total				
	M:	57.32	63.00	60.24
	SD:	8.29	7.50	8.37
	N:	74	78	152

Table 6. Means and Standard Deviations for Verbal Interaction

Ability	Type of control: Learner	Program	Total
		Homogeneous	
High			
M:	163.00	95.17	129.08
SD:	57.98	37.11	58.39
N:	6	6	12
Low			
M:	87.50	55.00	71.25
SD:	63.65	19.95	48.07
N:	6	6	12
Total			
M:	125.25	75.08	100.17
SD:	70.18	35.31	60.07
N:	12	12	24
		Heterogeneous	
High			
M:	160.25	125.50	142.88
SD:	51.91	40.01	46.75
N:	4	4	8
Low			
M:	125.50	118.00	121.75
SD:	46.60	45.28	42.72
N:	4	4	8
Total			
M:	142.88	121.75	132.31
SD:	49.30	39.76	44.62
N:	8	8	16
		Combined	
High			
M:	161.90	107.30	134.60
SD:	52.61	39.29	53.17
N:	10	10	20
Low			
M:	102.70	80.20	91.45
SD:	57.97	44.30	51.52
N:	10	10	20
Total			
M:	132.30	93.75	113.03
SD:	61.85	43.06	56.11
N:	20	20	40

Table 7. Means, Standard Deviations, Correlations with Achievement, and Probabilities of Interaction Categories

Category	M	SD	r	p
Reading information	26.38	19.13	.275	.085
Asking questions	10.55	6.38	.178	.273
Giving answers	30.95	15.35	.220	.173
Seeking clarification	2.68	2.98	.315	.047
Providing explanations	15.33	15.14	.483	.002
Making comments	5.60	4.19	-.099	.542
Energizing the group	13.93	11.48	.224	.164
Suggesting directions	7.58	5.38	-.120	.462
Entering group response	36.80	23.89	.227	.159
Showing off-task behavior	9.73	13.50	-.445	.004
Verbal interaction	113.03	56.11	.349	.027
Total group discourse	159.55	70.00	.271	.090