DOCUMENT RESUME

ED 436 133 IR 019 758

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TITLE	Effects of Learning Structure and Summarization during Computer-Based Instruction.
PUB DATE	1999-02-00
NOTE	12p.; In: Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology [AECT] (21st, Houston, TX, February 10-14, 1999); see IR 019 753.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Chemistry; Comparative Analysis; *Computer Assisted Instruction; *Cooperative Learning; Grade 9; High Schools; Instructional Design; *Instructional Effectiveness; Interaction; Intermode Differences; *Learning Strategies; Physics; Pretests Posttests; Science Instruction; Student Attitudes; Student Behavior; Time on Task
IDENTIFIERS	*Summarization

ABSTRACT

The purpose of this study was to investigate the effects of learning strategy and summarization within a computer-based chemistry and physics program. High school students worked individually or in cooperative dyads to complete science instruction; half of them completed summaries over the instructional content when directed to do so. The study examined the effects of learning strategy and summarization on posttest and enroute performance, attitude, time-on-task, and cooperative interaction behaviors. (Contains 53 references.) (Author/MES)

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Abstract

The purpose of this study was to investigate the effects of learning strategy and summarization within a computer-based chemistry and physics program. Students worked individually or in cooperative dyads to complete science instruction; half of them completed summaries over the instructional content when directed to do so. The study examined the effects of learning strategy and summarization on posttest and enroute performance, attitude, time-on-task, and cooperative interaction behaviors.

Introduction

Cooperative learning is an instructional strategy often used by teachers for classroom application. While some teachers implement cooperative learning because they believe it is effective in terms of student achievement, many teachers use cooperative learning to solve problems of classroom logistics. Teachers often group students around a computer to work together, a practice usually driven by the scarcity of computers in the schools. While this practice may be driven by necessity, teachers using limited resources must find ways for students to learn effectively while using computers in group situations.

A number of research studies have been conducted to investigate the effectiveness of cooperative learning. The effects of cooperative learning have often been studied in comparison to individual or competitive learning in situations ranging from kindergarten classrooms to courses offered on college campuses (Carrier & Sales, 1987; Cohen, 1990; Hooper, 1992a; Sharan, 1980; Slavin, 1980, 1988). Learner performance on cooperative tasks has been measured using text-based, television-based and computer-based instruction (Dalton, Hannafin & Hooper, 1989; Klein & Pridemore, 1992; Slavin, Stevens & Madden, 1988). Many studies have yielded positive results for achievement and attitudes when cooperative learning was implemented in classroom settings (Johnson & Johnson, 1989; Sharan, 1980; Slavin, 1990). However, the overall results of implementing cooperative learning with media such as computer-based instruction have been mixed at best.

Reviews of cooperative learning research are generally positive for achievement when cooperative learning is used in classroom settings. Slavin (1987) reviewed 35 studies which met the four conditions of cooperative learning and which used group rewards based on the sum of group members' individual learning; he reported that in 30 of those studies, researchers found significantly greater achievement for cooperative groups than control conditions. In a later review, Slavin (1990) noted that most cooperative learning studies measure achievement, and that more than half of those found significantly greater achievement for cooperative learning groups than for control conditions.

While the literature includes fewer studies on cooperative learning combined with computer-based instruction (CBI), some studies have reported significant achievement results when cooperative learning was used with CBI. Dalton, Hannafin & Hooper (1989) found that eighth-grade students who cooperated to complete a computer-based lesson on health significantly outperformed individuals completing the same lesson. Johnson, Johnson and Stanne (1985) reported that eighth-grade students who worked cooperatively to complete computer-assisted instruction performed better than those who worked individually or competitively. Other researchers found significant results for achievement when fourth, fifth, and sixth graders used cooperative CBI to learn math content (Hooper, 1992b; Hooper, Temiyakarn, & Williams, 1993).

However, not all researchers have found significant achievement effects for cooperative CBI when it was compared to individual CBI. Carrier & Sales (1987) found no significant achievement differences between college students who worked cooperatively and those who worked alone on either an immediate or delayed posttest. Webb (1987) reviewed 19 cooperative computer-based learning studies, and found that there were no significant achievement differences between cooperative groups and individuals for nine of them and that cooperative groups outperformed individuals in only five of those reviewed.

Another area of research focus has been the effect of cooperative computer-based instruction on affective variables. Many studies have reported mixed results for attitudes and affective variables in cooperative computer-based instruction. Dalton, Hannafin, & Hooper (1989) found that attitudes differ between high ability and low-ability students, and also between male and female students in cooperative groups versus the individual condition. Doran (1994) found that overall attitudes toward CBI were positive, but that attitudes toward learning structure for college students in cooperative, collaborative and individual conditions were mixed. However, Jones (1995) found that high school students working cooperatively to complete a CBI lesson on math content liked cooperative learning significantly more than those working as individuals liked working alone. Crooks (1995) found that college students in cooperative learning structures preferred to return to CBI significantly more than those in the individual conditions. Johnson, Johnson, & Stanne (1985) found that attitudes toward computer-based instruction did not vary, but that attitudes were significantly less positive for the competitive condition than for the cooperative and individual conditions.

In addition to affective measures, several studies have examined how students interact in a cooperative learning setting. To ensure appropriate interaction, students are usually trained to cooperate by behaving in specific ways in relation to their partner(s) and within the instructional environment. In a discussion of the conditions under which cooperative dyads become productive, Cohen (1994) notes that in CBI tasks, students often divide the labor into roles such as thinkist and typist rather than interacting, and that this can be avoided by preparing and instructing students regarding the appropriate levels of interaction during cooperation. In some studies, more specific instructions on how and when to interact resulted in higher achievement than did less specific directions or no directions (King, 1991; Meloth & Deering, 1992; O'Donnell, Dansereau, Hall, & Rocklin 1987).

Research into the types of interaction which yield the best achievement results has shown that behaviors such as asking and answering questions, giving and receiving help, and giving elaborated explanations have tended to improve achievement for students of all ability levels (King, 1990; Repman, 1993; Webb, 1982a, 1982b, 1983). Results showing that students who interact well tend to achieve more have prompted researchers to examine techniques for increasing or directing cooperative interaction. Some studies have used very elaborate strategies for directing and influencing student interactions during cooperative learning situations. Other researchers have required that learners follow a specific script and assume roles, or required learners to review or summarize key concepts (Dansereau, 1987; Larson, et. al, 1985). O'Donnell and Dansereau (1993) found that students who did not take notes over the content, but who reviewed cooperatively performed as well as those who took notes; additionally, students who expected to review individually but instead reviewed cooperatively with another student performed better than those who reviewed individually. Skaggs and her colleagues (1990) found that directing interaction to require oral summarization, elaboration, and other types of processing of technical content have impacted retention and recall of information.

Researchers have studied summarization as one form of interaction during cooperative learning. Findings generally show that achievement is enhanced when cooperative subjects are cued to summarize content and listen closely to detect errors or omissions in summaries (O'Donnell, Dansereau, Hall, & Rocklin, 1987; Lambiotte, et. al, 1987). Spurlin, Dansereau, O'Donnell, & Brooks (1986) found that cooperative subjects who take turns performing the roles of summarizer and listener score better on posttests than those who maintain static roles. These researchers also reported that distributed summary cues have a positive effect on achievement, recall, and transfer. Others who have studied learner interactions based on assigned roles during summarization found no overall performance differences for role assignments or summary type (O'Donnell, et. al, 1987). In addition, Sherman and Klein (1995) found that eighth graders who completed a cooperative, computer-based science lesson with distributed cueing performed significantly better than those in dyads who were not cued to summarize and explain the material to their partners.

The purpose of the current study was to investigate the effects of learning structure and summarization on achievement, enroute performance, and attitudes. High-school students worked either cooperatively or individually to learn science content from a computer-based lesson. Half of the students in both learning structures were required to write summaries according to instructions embedded throughout the instructional program which directed them to summarize the main points of the section just covered. These directions were similar to those used in other cooperative learning studies (Dansereau, 1987; O'Donnell & Dansereau, 1993; Sherman & Klein, 1995).

The instruction, practice, and feedback were provided by a computer-based program designed to provide an interactive learning environment, including an on-line periodic table of elements, an animation program illustrating internal atomic structure, and animations of specific chemical compounds.

The major research questions addressed in this study were:

1. What is the effect of cooperative versus individual learning structure on the posttest performance, enroute performance, attitudes, and time-on-task for subjects completing an interactive CBI science program?
2. What is the effect of summarization versus no summarization on the posttest performance, enroute performance, attitudes, and time-on-task for subjects completing an interactive science CBI program?
3. Does requiring dyads to write summaries during CBI influence cooperative interaction behaviors?

Method

Subjects

The subjects for this study were 78 ninth-grade students from a large, public high school in the southwest. All students were enrolled in a freshman ChemPhysics science class and had access to a computer lab during the hour of their science class. All students had been taught how to work together in cooperative situations by their teachers.

Materials

The materials for this study comprised a computer-based lesson on the periodic table of elements and the chemical and physical properties of elements. The lesson included a tutorial, an on-line periodic table of elements, and animated atomic models. The content of the materials was based on objectives and materials currently taught in the ChemPhysics course. The on-line tutorial included an introduction, a review of prerequisite knowledge, information on the development, structure and practical use of the table, practice questions, and feedback. There were also several sets of interactive exercises, which required that students access the table to complete the exercises correctly.

The introduction to the tutorial provided directions on how students should use the instruction, general navigation, how to interact with the on-line periodic table and animated atomic models, and how to get on-line help when necessary. Another section of the introduction covered the impact of this program on the students' course grade. The instructional segment of the program was divided into three sections. Students completed two sections on Days 1-3 of the study and one section on the last day. The first section introduced students to the program and navigation, and included screens explaining that the students' performance at the computer and on the posttest would count toward their course grade. Those in the summarization condition also saw two screens relating to the summaries; the first screen contained a description of the summaries to be written and the other contained an explanation of the summary directions they would see throughout the lessons. This introductory section consisted of 20 screens, five of which are interactive pages which taught students how access and use both the on-line periodic table and on-line help.

The actual ChemPhysics course content was presented in three lessons. Each lesson began with the objectives and an overview for the lesson. For the summarization condition, students saw two direction screens and two input screens in each section; there were 24 summarization screens in all. There were 81 instructional screens in the program and 19 selected-response practice questions. Lesson One consisted of two sections of information on the development and revision of the periodic table of elements. Lesson Two included two sections, which covered chemical and physical properties of elements and the Periodic Law that is the basis for the organization of the table. Lesson Three included two sections on the element key and the practical use of the key and table by chemists. Each lesson included two sets of practice questions, and provided the students with the number correct and points earned at the end of each section in the lesson.

Three types of interactive exercises were embedded within the program. The first type of constructed-response item required subjects to use the on-line periodic table to find specific properties of given elements; there were four sets of element characteristics exercises, which included four items each. The information was available from the Periodic Table, and the computer did not accept incorrect responses; feedback was provided for each item within each set of exercises. The second type of interactive exercise required students to fill in the three missing components in an element key. Six items requiring students to construct element keys from information available in the periodic table were included; the computer did not accept incorrect answers. The last type of interactive exercise dealt with atomic composition. In addition, there were six atomic composition items, which required the students to build atoms of the specified elements by placing protons, electrons and neutrons on a graphic of an atom shell. Students were allowed three attempts for each item. A total of 16 interactive practice items were distributed throughout the program.

Subjects had navigational control throughout the program, with a few exceptions. Subjects could not jump ahead in the program, but could return to previously-viewed screens within a section until they encountered a summary direction screen (summary version). Review was not permitted once students reached the selected-response practice questions at the end of each section.

The computer tutorial was supplemented by an on-line, interactive periodic table of elements, which provided the information normally available in any standard periodic table. In response to the subjects' input, the table also provided more specific information about each element and group of elements. From the table, subjects had access to the atomic animations, which displayed the atomic composition of each element (protons, neutrons, and electrons).

The on-line periodic table of elements looked just like a typical periodic table, except that the square for each atom displayed only the symbol for the atom. When a subject clicked on a particular atom's location, more detailed information appeared in a text section just to the right of the actual table. This information included the full name of the element, the atomic number and atomic weight, as well as typical properties of the element itself. Different groups were highlighted when the subject clicked a specific button regarding that group or type of element. The subject could also bring up detailed information about the different types of elements (such as noble gases, or alkali metals) by clicking on specific, labeled buttons. The table was accessible by the subjects when they were completing the tutorial, the practice exercises, and interactive exercises.

The table also featured a search engine that located elements when the name of an element, or partial name, was typed in to the search engine dialog box. Subjects could locate information about an element even if they did not know the chemical symbol for the element. Once the element was found, the square for that element was highlighted and the detailed information for that element was displayed. If an entry could not be located within the table, a message came back stating that a match could not be found and suggesting that the subject check the spelling of the element name.

The periodic table of elements was linked to an atomic animator. Based on the selection made by the student, the animator displayed the atomic structure of any element, which was selected, or active at the time the Show Atom button was clicked. The atoms were accurately represented by up to 18 protons, neutrons, or electrons. Atoms with an atomic number greater than 18 were represented by the same atom display as 18, but the actual numbers of protons, neutrons, and electrons were accurately stated within the diagram. Up to the atomic number of 18, the elements were represented with accurate numbers of protons and neutrons in the nucleus of the atom, orbited by the correct number of electrons displayed in the correct levels. For example, the atomic animation for carbon (atomic number = 6) showed six yellow protons and six red neutrons in the nucleus, with two blue electrons in the first level and four more blue ones in the second level. The electrons circled the nucleus continuously at a constant distance when the animator was running. The subject could stop the animation at any time by clicking the Hide Atom button. The animator could only be launched from the table, and not directly from the tutorial screens.

The atomic animator was also accessed directly from several instructional screens on atomic composition. The students could view an animation by clicking on the buttons provided on related instructional screens, and were then returned to that same screen from which the Hide Atom button was clicked.

From instructional screens containing information about or references to compound composition, students were directed to access another animator, which displayed a specific set of compounds as the combination of atoms graphically represented. Subjects saw the selected compound, which was accompanied by a brief descriptive text message. Each compound animation displayed the actual atomic composition of the compound. For example, water displayed one oxygen atom and two hydrogen atoms, which were all linked at their outer electron levels and shared the electrons necessary to fill the all outer levels of all three. For each animation, a descriptive compound-specific message was displayed, and the message was visible until the subjects dismissed it with a mouse-click.

A summarization and a no summary (control) version of the computer lesson were developed. Both versions included all of the instructional elements described above. The summarization version also included 24 summary screens, 12 that directed students to list the main points covered on the information in the preceding instructional segment and 12 where the summaries were typed into text fields. Each section included two summary screens.

The summarization version for the cooperative treatment directed students to work together to summarize the main points of the information and directed students by name to type in the summary. Students in cooperative dyads were directed by name to take turns typing in the summaries. The summarization version for the individual treatment directed students to summarize the main points and type in the summary each time. Subjects in the no summary (control) conditions received exactly the same ChemPhysics instruction, practice exercises, and interactive exercises, but they did not see the summarization screens directing them to recall and type in summaries of the information presented in the computer-based tutorial.

Procedures

This study included four different treatment groups: cooperative-summary, cooperative-no summary, individual-summary and individual-no summary. Twenty individuals were assigned to each summarization condition; in the cooperative conditions, 20 students were assigned to summarization condition and 18 to the no-summary condition. Subjects in the cooperative-summary group worked in dyads to complete the computer lesson and were provided with directions to summarize main points during the instruction. Those subjects in the cooperative-no summary group worked in dyads to complete the lesson but did not receive summary directions. In the individual-summary group, subjects worked alone to complete the lessons and were provided with summary directions while those in the individual-no summary group completed the lessons but did not receive these directions. All subjects implemented their treatment-specific computer lesson over four consecutive school days.

Students in three ChemPhysics classes were randomly assigned to either a cooperative or individual treatment condition. Subjects assigned to cooperative treatments were randomly assigned a partner in the same class. Approximately half the subjects in each class were randomly assigned to the summarization treatment and half were randomly assigned to the no summary treatment.

Subjects in the cooperative-summary condition worked in assigned pairs to complete the computer lesson. These dyads were told to work together to complete the exercises, and that each would be assigned the score achieved by the pair for correct completion of the exercises. At specific points during the lessons, pairs were directed to work together to summarize the main points of the section. They were also directed to take turns typing summaries into the computer, and that their grades on the exercises and the posttest were part of their semester grade for the course. All subjects were informed that they would take the posttest individually. Finally, each subject completed an attitude survey immediately before taking the posttest.

Subjects in the cooperative-no summary condition worked in assigned pairs to complete the lessons. These dyads were told to work together to complete the exercises and that each would be assigned the score achieved by the pair for correct completion of the exercises; they were told that their grades on the exercises and the posttest would be part of their semester grade for the course. All subjects were informed that they would take the posttest individually. Each subject completed an attitude survey immediately before taking the posttest.

Subjects in the individual-summary condition worked alone at the computer to complete the lessons. At specific points in the instruction, they were directed by name to summarize the main points of the section. Individuals were told to complete all the exercises and that they would be assigned a score for correct completion of the exercises; they were told that their grades on the exercises and the posttest would be part of their semester course grade. All subjects were informed that they would take the posttest individually. Each subject completed an attitude survey immediately before taking the posttest.

Subjects in the individual-no summary condition worked alone at the computer to complete the lessons. They were told that they would be assigned a score based on correct completion of the exercises and that their grades on the exercises and the posttest would be part of their semester grade for the course. All subjects were informed that they would take the posttest individually. Finally, each subject completed an attitude survey immediately before taking the posttest.

Criterion Measures

The criterion measures for this study were a posttest and an attitude survey. Interaction behavior, time-on-task, and enroute performance were also examined. Achievement was measured by a 25-item, paper and pencil posttest. All subjects completed the posttest individually; they were informed at the outset that their posttest grade would be part of their ChemPhysics course grade. The posttest covered all of the objectives taught and practiced within the computer lesson, as well as all the objectives typically covered by the ChemPhysics tests over this segment of material for the course. The posttest consisted of 17 selected response items and eight constructed response items. The Kuder-Richardson reliability estimate for the posttest was .65. The experimenter scored all posttests using an answer key that included correct answers and possible points per item.

Attitude was measured by a pencil and paper survey administered just before the posttest. The survey consisted of 10 items which subjects responded to using a five-point Likert-type scale. Items measured the three attitude components of confidence, satisfaction, and continuing motivation. The Cronbach's Alpha reliability for the attitude survey was .74.

Subjects' behaviors during the study were recorded by trained observers using checklists for consistent tracking and recording; the checklist and instructions were adapted from Klein & Pridemore (1994). Subjects in cooperative conditions were observed for 30-second intervals to determine the type and frequency of interactive behaviors. Each observer recorded interactions for all cooperating dyads, watching each dyad for 30 seconds before moving to the next dyad. Observers noted how often a dyad discussed the material presented, how often members of a dyad discussed navigation, program requirements or task parameters, and how often students in a dyad worked individually. Off-task behaviors and conversation were also tracked. Observers also noted whether subjects shared keyboarding and summarizing responsibilities. Prior to recording observations during the study, the observers met to watch a videotape of a pair of ninth graders working together to complete the instructional program and discuss the categories of behavior. There was a discussion about the types of interaction behaviors and the observers practiced recording interactions as they watched several segments of the videotape. Inter-rater reliability was measured after training; observers were shown a different segment of video and were directed to record all interaction behaviors on the checklist. Each observer's record sheet was compared to the record sheet completed by the researcher. Inter-rater reliability exceeded 90 percent.

Enroute performance was measured using scores on the 19 selected-response practice questions. Subjects in the cooperative condition worked together to complete the items, and each received the score achieved by the pair working together. Individuals completed the same questions and received credit for the number completed correctly.

Design and Data Analysis

This study was a posttest-only, control group design. It was a 2 learning strategy (cooperative versus individual) x 2 summarization (summary versus no summary) factorial study. Both learning strategy and level of summarization were between-subjects variables. Analysis of variance (ANOVA) was conducted on posttest and enroute performance scores. Attitude scores were analyzed using MANOVA. Univariate analyses were performed on individual survey items. Time data were also analyzed using MANOVA with instructional and practice time as the dependent variables. Univariate analyses were conducted on the time spent on different sections of the program. Observation data gathered on interaction behaviors for dyads were analyzed using T-tests of significance.

Results

Posttest Performance

The overall mean for the posttest was 27.95 (SD = 3.59), or 74 percent. The mean posttest score for subjects in the cooperative condition was 26.95 (SD = 2.88) and was 28.58 (SD = 3.10) for those in the individual condition. Posttest mean score was 27.73 (SD = 4.15) for students in the summary condition and 28.38 (SD = 3.14) in the no summary condition. Analysis of variance (ANOVA) conducted on posttest scores revealed no significant effects for any condition.

Enroute Performance

Enroute performance scores were reported as the number of practice questions completed correctly for all conditions. The overall mean score for enroute performance was 14.22 (SD = 2.79), or 75 percent. The mean enroute score for subjects in the cooperative condition was 13.53 (SD = 1.98) and was 14.55 (SD = 2.84) for those in the individual condition. The enroute mean score was 13.30 (SD = 2.87) for students in the summary condition and 15.17 (SD = 2.06) in the no summary condition. Analysis of variance for enroute scores (practice questions) showed a significant difference between students who wrote summaries and those who did not, F (1,55) = 7.15, p = .01. Examination of the mean scores revealed that students in the no-summary condition (M = 15.17) performed better on enroute practice items than those who summarized (M = 13.30).

Attitude

Results indicated that subjects enjoyed using the computer program (M = 2.01) and would like to use computer programs more often (M = 1.86). Students generally reported a positive attitude toward the effectiveness of the exercises (M = 2.22), the atomic animations (M = 2.08), and the on-line periodic table (M = 1.89). Student attitudes toward the learning condition showed that those who worked cooperatively liked working with a partner (M = 2.08), and those who worked individually liked working alone (M = 2.28). MANOVA conducted on the attitude data showed no significance for any attitude items (alpha = .05).

Time–on–Task

Time-on-task was broken out as instruction time and practice time. The overall mean for instructional time was 55.59 (SD = 16.37) minutes. The mean instructional time for the cooperative condition was 50.73 (SD = 13.95) minutes and was 57.89 (SD = 17.07) minutes for those in the individual condition. Instructional time means were 55.17 (SD = 16.48) minutes for those in the summary condition and 56.02 (SD = 16.53) minutes in the no summary condition. The overall mean for practice time was 32.69 (SD = 8.91) minutes. The mean practice time for the cooperative condition was 31.50 (SD = 9.55) minutes and was 33.25 (SD = 8.65) minutes for those in the individual condition. Practice time means were 29.85 (SD = 7.49) minutes for those in the summary condition and 35.62 (SD = 9.41) minutes in the no summary condition. MANOVA was conducted on time data using instructional and practice time as the dependent variables. MANOVA revealed that summary condition had a significant effect on time-on-task, $F(2,54) = 6.04$, $p < .01$. Univariate analysis revealed that students who summarized spent less time on practice items than those who did not summarize, F (1,55) = 11.95, $p < .01$ (see Table 7). Univariate analyses also revealed a significant interaction between learning strategy and summary condition $F(1,55) = 6.76$, $p < .01$. Follow-up Scheffé multiple comparison tests indicated that the practice time mean for those in the individual-no summary group (M = 34.22) was significantly different from the means for those in the cooperative-summary (M = 24.99) group. The Scheffé test also indicated that the practice time mean for the cooperative-no summary (M = 38.72) group was significantly different from the cooperative-summary (M = 24.99) group.

Interaction Behaviors

Observational data were gathered during the course of the study for cooperating pairs only. The mean for observed helping behaviors was 8.39 (SD = 4.54) for no-summary and was 15.10 (SD = 3.90) for summary condition pairs. The mean for task-related behavior was 2.09 (SD = 1.57) for no-summary and was 3.00 (SD = 1.66) for summary dyads. The mean for on-task individual behaviors was 2.82 (SD = 2.97) for pairs in the no summary condition and was 2.93 (SD = 2.50) for pairs in the summary condition. Finally, the mean for off-task behavior was 1.45 (SD = 2.02) for no-summary pairs and was 3.53 (SD = 4.93) for summary pairs. T-tests run on interaction behaviors revealed that subjects in the cooperative-summary condition exhibited significantly more helping behaviors than those in the cooperative no-summary condition, $t(30) = 5.59$, $p < .01$. Subjects in the cooperative-summary group also exhibited significantly more task-related behaviors than those in the cooperative no-summary condition, $t(30) = 2.55$, $p = .016$. Differences were not significant for the two remaining interaction behaviors.

Discussion

The purpose of this study was to investigate the effects of learning strategy and summarization within a computer-based chemistry and physics program. Students worked individually or in cooperative dyads to complete science instruction; half of them completed summaries of the instructional content when directed to do so. The study examined the effects of learning strategy and summarization on posttest and enroute performance, attitude, time-on-task, and interaction behaviors.

Results indicated no significant differences for posttest performance. One possible explanation for this result lies in the power of aligned and well-designed instructional materials. Subjects in this study used a competency-based instructional package developed to address each of Gagne's nine events of instruction. The computer program introduced material in prerequisite order and provided appropriate practice and feedback (Gagne, 1985; Sullivan and Higgins, 1983). It is possible that the design of the materials overrode the effects of the potential differences, which were investigated via the experimental conditions. The design of the ChemPhysics materials supplemented by the on-line Periodic Table and atom animation supports the theory of Anderson, Reder, and Simon, (1996) that "combining abstract instruction with specific concrete examples is better than either one alone" (pg. 8). In fact, Anderson, Reder, and Simon, (1996) cite a number of studies that support the contention that the combination of abstract and concrete concepts is a powerful method of instruction.

Other researchers have suggested that the performance of individuals and cooperative groups is often equal when well-designed instruction is used by all students. Bossert (1989) indicated that studies often compare cooperative learning conditions to whole-class methods, or compare well-designed cooperative learning structures to poorly-designed individual situations. In studies utilizing well-designed instruction across all conditions, posttest results do not consistently show significant differences for cooperative learning (Cavalier 1996; Klein & Doran, 1997; Slavin & Karweit, 1984; Slavin, Madden, & Leavey, 1984; Snyder & Sullivan, 1995).

Results also indicated no significant enroute performance difference between those working in cooperative dyads and those working alone. Enroute items consisted of selected-response items, which were aligned to the instructional content sections, presented. These items measured the acquisition of factual knowledge, not complex skills. Cooperative learning researchers have found that complex skills such as higher order reasoning provide the best opportunity for cooperative structures to impact performance (Bossert, 1989; Hooper & Hannafin, 1988). It is likely that the level of processing or performance required for students to answer the selected response items was not sufficiently demanding for those in the cooperative structure to benefit from collaboration.

Another factor in the lack of differences for enroute performance may be due to the consistency of the computer-based instruction. Bossert (1989) notes that in many cooperative learning studies, teachers often give specific instructions, explanations, encouragement, and feedback to students in the cooperative situation but do not give them to individual students. Computer-based instruction provides consistency for students in both cooperative and individual conditions.

Results for enroute performance indicated that practice scores for students who did not write summaries were significantly higher than for those who wrote summaries. It is likely that the difference in scores resulting from summary conditions was caused by the amount of time spent on practice. Results for time-on-task showed that students who summarized the material spent significantly less time on the practice items than students who did not write summaries. Students who wrote summaries may have felt pressured to spend less time on the practice questions, and therefore may have been more prone to answer incorrectly. The lower enroute performance scores for those in the summary condition seem to indicate that those students had insufficient time to complete the practice items.

Results for time-on-task also indicated a significant interaction between learning strategy and summary condition. Generally, it might be expected that students working in cooperative dyads would take more time to complete practice items than those working individually because they had to interact regarding the material and agree on an answer. However, this was only the case for those in the cooperative no-summary condition. Cooperative pairs in the summary condition spent less time on practice items than the individuals. Again, it is possible that the time limitation of class periods accounts for this result. Students who had spent time cooperating throughout the instruction and who then wrote summaries likely had the least time remaining for the practice items. Cooperative students who did not write summaries had more time remaining for practice.

Results for time on instruction showed no significant differences for students in any of the conditions. Knowledge that summaries would be required apparently did not impact time-on-task for students in either learning strategy condition. Although it is generally expected that students who cooperate require more time to complete instruction (Slavin, 1990), there are some researchers who indicate that computer-based instruction can be as efficient for those who cooperate as for those who work individually (Klein & Doran, 1997). While it was expected that students in cooperative dyads would expend more time than those who worked individually, the results of this study suggest that under some conditions, students can learn as efficiently when cooperating if the instruction is specifically written for cooperative interaction to take place.

Attitude results regarding the actual computer-based program were generally positive. The results of the study indicate that students enjoyed learning about ChemPhysics by using the computer program and would like to learn more by using other computer programs. This could be reflective of the instructional quality and interactive level of the program itself, which encourages active involvement (Bright, 1983; Caldwell, 1980; Hannafin & Peck, 1988). The attitude results also show positive student reactions to the effectiveness of the interactive exercises, the atomic animations and the on-line, interactive periodic table. However, these positive results may be as much a response to the actual interactivity of those program features as to their effectiveness as learning tools. It is also possible that these attitude results could instead be attributed to a novelty effect that students experienced because class was held in the computer lab where they used computers instead of in the typical lecture and lab format (Bright, 1983; Hannafin & Peck, 1988).

Attitude results regarding the learning structure from the study were mostly consistent with positive attitude results reported in other cooperative learning studies. Attitude scores show that students expressed positive feelings about the particular learning strategy to which they were assigned. Positive attitudes for cooperative learning structures have been reported by a number of researchers (Crooks, 1995; Jones, 1995; Sherman & Klein, 1995; Slavin, 1980).

Results from the study also indicated that students in the two cooperative conditions interacted together in somewhat different ways. Student pairs in the summary condition exhibited more helping behaviors than those in the no-summary condition. Dyads in the summary condition also interacted more regarding the instructional content of the program. It is likely that these differences were the result of the additional interaction required of the summary condition, as the students who wrote summaries had more opportunities during which they could work together. While the observed interaction differences were statistically significant, further consideration of the actual means for observed behavior indicate that the differences were quite small because the number of observed behaviors overall was quite small. Since differences in observed interactions were small and did not impact posttest performance, it is important not to over-interpret the results for interactions.

This study has some implications for the application and design of computer-based instruction. It is possible that educators can compensate for the realities of limited resources in schools by implementing well-designed computer-based instruction with cooperative learning. This study indicates that computer-based instruction designed and developed following a systems approach may enable students working together to perform almost as well as students working alone. Since technology to deliver computer-based instruction to individuals may not be consistently available in public schools, the availability of resources is a legitimate concern for teachers and administrators.

The current study also suggests that CBI developers must consider practical time constraints prior to including strategies such as cooperative learning or summarization in their programs. The inclusion of these strategies may have unintended consequences such as a decrease in practice time especially if students are not provided enough time to complete other portions of the lesson. Additional research should explore the variables used in this study for a longer duration of time. It might also be worthwhile to investigate the performance effects of summarization during CBI in the absence of other forms of practice.

Future cooperative learning research should also continue to use well-designed instruction that teaches school-age children existing curricular objectives (Anderson, Reder, and Simon, 1997). While teacher-directed and whole-class activities still dominate schoolroom practices, there is considerable pressure to change to other forms of instruction. Therefore, there is value in the continued investigation of how to employ well-designed CBI to support learning in small group situations.

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