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The effects of cued interaction and ability grouping during cooperative computer-based science instruction

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THE EFFECTS OF CUED INTERACTION AND ABILITY GROUPING DURING COOPERATIVE COMPUTER-BASED SCIENCE INSTRUCTION

by

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ABSTRACT

The purpose of this study was to investigate the effects of verbal interaction cues and ability grouping within a cooperative learning computer-based instructional science program. Two-hundred and thirty-one junior high school students enrolled in a required eighth-grade science class were blocked by ability and randomly assigned to one of three different types of dyads. These dyads consisted of homogeneous lower-ability, homogeneous higher-ability, or heterogeneous mixed-ability student pairs. Each dyad was then randomly assigned to a computer program that either did or did not contain verbal interaction cues designed to facilitate summarizing and explaining between partners at various points throughout the program. The study examined the effects of interaction cues and ability grouping on performance, time, en route behavior, and attitudes toward the instruction.

Results indicated that students who used the cued version of the program performed significantly better on the posttest than students who used the noncued version. These results were consistent for both higher and lower-ability students. Dyads assigned to the cued version also performed significantly better on the practice items than dyads assigned to the noncued version.

Results for time revealed that subjects who used the cued version spent significantly more time on interaction screens than those who used the noncued version. Direct observation of student interaction indicated that students in cued dyads exhibited significantly more summarizing behaviors and helping

behaviors than students in the noncued dyads. Ability grouping did not significantly influence summarizing or helping behaviors. However, students in higher-ability dyads exhibited significantly less off-task behavior than students in mixed-ability and lower-ability dyads.

The results from this study help support previous research on the effects of providing cued in cooperative learning settings. Implications for designing computer-based instruction are provided.

DEDICATION

This work is dedicated to the memory of Bill Ferrell.

ACKNOWLEDGEMENTS

I am very grateful for all the hard work, time, and patience given to me by Dr. James D. Klein, my committee chair. I would also like to thank the other members of my committee: Dr. Howard Sullivan, Dr. Wilhelmina Savenye, Dr. Don Freeman, and Dr. Nancy Haas. I am also thankful for all the assistance provided by my second family at Hendrix. My mother also deserves credit for getting me into this mess in the first place. Most importantly, I want to thank my wife Shelly for strongly supporting me from the very beginning. This work is the result of her many sacrifices as well as mine.

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CHAPTER I

INTRODUCTION

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

Although grouping students around computers may help ease computer-shortage problems, assigning more than one student to a computer can lead to other problems. For example, if more than one student share a computer, how will all students be equally involved in the instruction? How will all students remain on task? How will the slower students keep up with the faster students? How will all students receive adequate practice and feedback?

Unfortunately, very few computer programs exist that incorporate instructional strategies specific for learning groups. Software developers have generally assumed that computer-based instruction (CBI) programs should and would be utilized by individual users (Cosden, 1989). The individualistic nature

of CBI programs may impact the interaction between group members and the computer program. This, in turn, may diminish the effectiveness of the program.

Since most CBI programs are not designed for group use, teachers must apply some type of small group learning strategy to the lesson in order to maximize the program's effectiveness for all group members. Today, the most common and widely researched small group learning strategies fall into a category called "cooperative learning." The following paragraphs describe the basic components of cooperative learning and examine what the research literature reveals about the effectiveness of cooperative learning strategies when they are applied to CBI lessons.

Cooperative Learning

Generally, instructional programs considered "cooperative learning" incorporate four distinct strategies for structuring, directing, and managing group work. These strategies include individual accountability, positive interdependence, face-to-face interaction, and the facilitation and evaluation of interpersonal social skills (Johnson, Johnson, & Holubec, 1990; Slavin, 1980).

Individual accountability refers to the condition that students are ultimately responsible for individually learning all the material even though they will be working in groups. Strategies such as individual testing must be included in the lesson design to hold students individually accountable for learning all the material. Other common examples of individual accountability include individual homework assignments and the random selection of one group member's work to be graded on behalf of the entire group.

Positive interdependence refers to strategies designed to make students within groups feel that they can succeed only if all group members, including

themselves, succeed (Deutsch, 1949; Johnson, et al., 1990). Two distinct types of positive interdependence have been identified and researched. These include reward interdependence and task interdependence (Slavin, 1983). Reward interdependence exists within a lesson when the points, grade, and/or recognition earned by a team depend on the overall performance of all team members. Task interdependence refers to conditions in which the task or role a group member assumes is dependent on the tasks or roles of other students in the group. An example would be a group project in which the successful completion of a presentation poster was the group goal. One student might be responsible for locating and recording information to be included on the poster, and another might be responsible for drawing and writing on the poster itself. The students performing the two tasks, locating and presenting information, would depend on each other for successfully accomplishing the goal.

In addition to individual accountability and positive interdependence, a third component designed to maximize the effectiveness of a cooperative learning lesson includes providing the opportunity for face-to-face interaction. Face-to-face interaction is established when all group members can verbally and physically interact with each other throughout the lesson. This can be accomplished by maintaining group sizes between two and six members, and by physically seating group members in ways that allow them to look at each other, talk with each other, and share all materials (Johnson et al., 1990).

Another necessary component of cooperative learning includes strategies to facilitate appropriate interpersonal and small group social skills (Johnson et al., 1990). Because personal interactions are encouraged in cooperative learning, students must be taught the social or collaborative skills necessary to function constructively as a team. The facilitation and evaluation of these skills are an

important element within the structure of a cooperative learning lesson. Some of these collaborative skills include carrying out assigned tasks and roles, encouraging participation, giving direction to the group's work, offering to explain or clarify, and verbally accepting and supporting each other (Johnson et al., 1990). Since these skills must be taught to students, cooperative lessons should provide examples of appropriate collaborative behavior and feedback on the use of these skills.

A large number of research studies support the use of the four components of cooperative learning. Studies comparing cooperative learning with individual and competitively structured lessons indicate improved performance and attitudes when the four essential components have been applied. Four different meta-analyses performed on the results from over 400 experiments comparing cooperative, competitive, and individualistic goal structures show overall significant gains in achievement for students in cooperative groups (Johnson & Johnson, 1989; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Slavin, 1980, 1983). Although some of the studies included in these meta-analyses indicated no significant differences in achievement, cooperative learning was, in general, no worse than any other method. It is important to note, however, that virtually none of the studies included in the analyses utilized computers as tools or resources as part of the lesson.

Cooperative Learning with Computers

Research studies dealing with the application of cooperative learning in CBI lessons have been published only in the last 10 years. An ERIC-CD ROM search of experiments comparing cooperative and individual CBI revealed ten studies published from 1984-1994. The procedures carried out within most of the studies were similar. Student groups consisting of two individuals were given

instruction on the social skills necessary for constructive group performance. Various forms of individual accountability and positive interdependence were structured into the lesson design. Performance and attitudes for these cooperative dyads were compared to individuals utilizing the same computer program.

In general, achievement results for cooperative learning-CBI studies were mixed, with more consistent results present for various non-achievement measures. Six studies indicated significantly higher achievement scores for the cooperative groups (Dalton, Hannafin, & Hooper, 1989; Hooper, Temiyakarn, & Williams, 1993; Johnson, Johnson, & Stanne, 1985, 1986; Mevarech, Silber, & Fine, 1991; Mevarech, Stern, & Levita, 1987). Four studies showed no achievement main effects for cooperative dyads versus individuals (Carrier & Sales, 1987; Makuch, Robillard, & Yoder, 1992; Trowbridge & Durnin, 1984; Whyte, Knirk, Casey, & Willard, 1991).

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

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

Verbal Interaction

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

Recognizing the importance of verbal interaction between individuals within cooperative groups, a number of studies have been conducted in the past 10 years which have included variables designed to facilitate constructive verbal interaction. Dansereau (1985) developed a systematic interaction and processing strategy that has provided a structured method for cooperative dyads learning text-based material. This strategy consisted of assigning two different roles to cooperative dyad members. Both students were instructed to read a passage of

material. One student was assigned the role of summarizer, and was then instructed to verbally summarize the passage to the other group member. The other group member was assigned the role of listener, and was instructed to listen carefully and detect any errors or omissions. A number of studies testing the effects of this procedure have shown increased achievement for the pairs utilizing this structured interaction method (Lambiotte et al., 1987; McDonald, Larson, Dansereau, & Spurlin, 1985; O'Donnell, Dansereau, Hall, & Rocklin, 1987; O'Donnell, Rocklin, Dansereau, Hythecker, Young, & Lambiotte, 1987). Using a similar technique, Yager, Johnson, and Johnson (1985) determined that groups given structured oral discussions through role assignments achieved higher posttest scores than groups participating in unstructured oral discussions.

Ability Grouping

In addition to verbal interactions, another variable that may influence outcomes in a cooperative learning setting is ability grouping. Ability grouping refers to the assignment of students into cooperative groups based on general academic ability. Individual students are classified as low, medium, or high achievers and placed into cooperative groups. These groups may consist of students homogeneous in ability, or they may consist of representatives from two or three ability groups.

Heterogeneous groups are recommended in most cooperative learning models because they present opportunities for higher-ability learners to encourage and tutor lower-ability learners (Johnson et al., 1990; Slavin, 1980). Creating heterogeneous ability groups within cooperative learning lessons has recently been supported by Slavin (1993), who reviewed 27 studies dealing with ability grouping and found little or no achievement differences between students grouped heterogeneously versus homogeneously by ability. The lower-ability

students, however, did indicate more favorable attitudes toward learning when grouped with students of higher ability.

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

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

Although the results on ability grouping are mixed, it seems reasonable to assume that students paired with other students of similar ability will interact differently than students paired with other students of significantly greater or lesser ability. Since the amount and type of interaction has been shown to affect learning, the type of groups established may also affect learning within cooperative groups.

Purpose of Current Study

The present study was designed to investigate the effects of verbal interaction cues and ability grouping within a cooperative learning-CBI science program. The major independent variable in this study was the presence of cues embedded throughout a CBI program designed to facilitate verbal interaction between two learners sharing one computer. Each cooperative dyad was assigned to a computer program that either did or did not contain these verbal interaction cues.

The cues used in this study were similar to those demonstrating positive results in non-CBI studies (Dansereau, 1985; Yager et al., 1985). As each cooperative dyad assigned to the cued version progressed through the science CBI program, the computer prompted individuals within each dyad to verbally interact by directing them to summarize, explain, or listen to the other member of their dyad.

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

The dependent measures in this study included practice item performance, posttest performance, and attitudes toward the program and working with a partner. Measurements were also taken regarding the amount of time each dyad spent on different parts of the program. Time spent on instruction, practice problems, and interaction screens were measured separately. A sample of dyads were also videotaped, and the nature of interactions within each dyad was observed. These observations included the specific behaviors cued by the

program (summarizing, explaining, identifying errors, and asking for help) as well as behaviors not addressed by the cues (receiving solicited and unsolicited help, verbal encouragement, and off-task behavior).

The major research questions addressed in this study were:

1. What is the effect of verbal interaction cues on the performance, attitudes, group member interaction, and en-route behaviors of students participating in a cooperative learning-CBI program?

2. What is the effect of ability grouping on the performance, attitudes, group member interaction, and en-route behaviors of students participating in a cooperative learning-CBI program?

3. How will verbal interaction cues interact with ability grouping to affect the performance, attitudes, group member interaction, and en-route behaviors of students participating in a cooperative learning-CBI program?

CHAPTER II

METHOD

Subjects

Two-hundred and thirty-one students from a junior high school in a middle-class socioeconomic, metropolitan area were the subjects for this study. The school was one of 11 junior high schools in a large school district serving approximately 67,000 students. The subjects were enrolled in a required one-semester, eighth-grade general science class. This science course followed a curriculum that incorporated the use of cooperative learning strategies into most laboratory investigations and activities. All students from the eighth-grade science classes participated in the study; however, data obtained from the special education students with severe learning disabilities and from the students who did not speak or read English were excluded from the study.

Materials

A computer-based instruction (CBI) science program entitled *Designing Controlled Experiments* was the source of instruction for this study. This Hypercard-based program consisted of four distinct parts: (a) the program introduction, (b) Lesson One: The Steps in the Scientific Method, (c) Lesson Two: The Parts of a Controlled Experiment, and (d) Lesson Three: Designing Controlled Experiments. Appendix A includes a complete list of objectives for each of the three lessons presented in the program.

The program introduction consisted of eight information screens which provided an orientation for the students regarding the successful use of the program itself. This introduction began by prompting the students to enter their assigned group number as well as their first names, thus enabling the computer to direct each student by name to perform specific tasks throughout the instruction. The introduction then presented a brief description of the three lessons covered in the program, followed by a description of the function and use of the navigation buttons. Practice was provided on the use of these buttons.

Specific information about the cooperative nature of the program was presented next. Because the program was specifically designed for two users sharing one computer, the grading of both individual and group performance was described in detail. The program informed the students that the score earned for this CBI activity was to be counted toward their semester grade. The program then stated that two methods of grading were to be used to determine the total number of points both students earn. One grade came from the points both students earn together on the practice problems presented throughout the program. The other grade came from each student's individual performance on a written posttest administered on the day following the completion of the program.

The introduction then encouraged both students to help each other learn the information presented in the three lessons. This encouragement consisted of reminding the students to share various responsibilities throughout each lesson. The program called on both learners by name to use the mouse at different times within the introduction, and the students were informed that they were not always going to be prompted to share the mouse and keyboarding responsibilities. The program also stated that the students should remind each

other to share throughout the three lessons. Next, the program reviewed some helpful cooperative learning roles that the students should share at times throughout the program. These role descriptions included the "summarizer" who was instructed to verbally summarize a unit of information, the "explainer" who was instructed to explain examples presented in the program, and the "listener" who was instructed to listen carefully to the summarizer or explainer and ask questions about things that were unclear, left out, or in error. Because the students had experience with formal cooperative learning techniques, these roles were already familiar to them.

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

Lesson One: The Steps in the Scientific Method. The first lesson in the program taught the steps in the scientific method and were broken up into two parts. The first part covered making observations, identifying problems, and choosing hypotheses. Twenty information, example, and review screens were presented in this first part. Six multiple-choice practice problems were then presented, and a group score was displayed. Feedback for all practice items throughout the program included knowledge of correct result. The second part of Lesson One included 24 information, example, and review screens covering making predictions, designing experiments, and analyzing data/conclusions. Three multiple-choice practice problems were then presented followed by the total number of practice problems answered correctly.

Lesson Two: The Parts of a Controlled Experiment. The second lesson covered the parts of a controlled experiment. This lesson was also divided into two parts, with practice problems and group scores presented after the instruction. The first part of the second lesson consisted of 23 information,

example, and review screens covering independent and dependent variables. Three multiple-choice practice items were presented following the first part of Lesson Two. The second part of Lesson Two presented 26 information, example, and review screens covering extraneous variables, variable groups, and control groups. Five multiple-choice practice items were presented after the instruction, followed by the total number of practice problem items answered correctly for the first two lessons.

Lesson Three: Designing Controlled Experiments. The third lesson was comprised of only one part. This lesson consisted of 33 information, example, and review screens presenting the four steps to be followed when designing a controlled experiment: (a) identify the independent and dependent variables, (b) determine the type of test to be performed, (c) determine at least three extraneous variables to be controlled between experimental groups, and (d) describe the control and variable groups by listing and labeling all variable types within each group. Two constructed-response practice problems were then presented after the instruction. These constructed-response items were evaluated by the students based on a set of criteria they used to judge various aspects of their answers. For example, after a group had listed and labeled the variables for an experiment designed to test a given hypothesis, the computer asked: "Does your variable group contain [appropriate variable name], and is it labeled as the independent variable?" The computer asked similar questions about the dependent and extraneous variables. The students were directed to click on "Yes" or "No" buttons as each statement applied to their constructed response. Although the previous 17 multiple-choice practice items were worth one point each, these final two constructed-response practice items were worth five points each. The constructed-response items were worth more points than

the multiple-choice items because they required the learners to apply at least five different skills taught throughout the program. Lesson three concluded by displaying the total number of practice problems answered correctly by the group for the entire program.

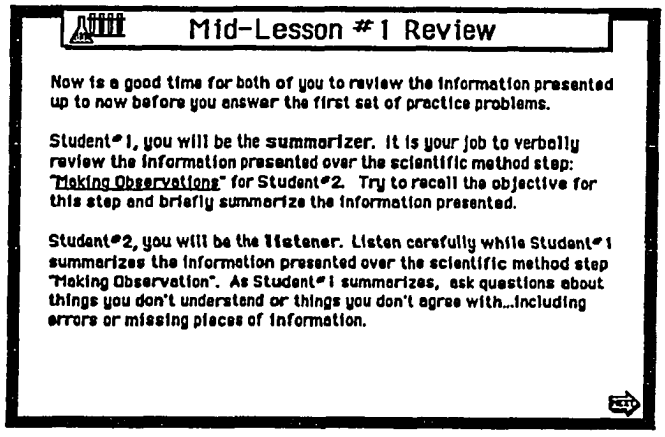
The computer program included the primary elements necessary for cooperative learning as prescribed by Johnson and Johnson (1989). Individual accountability was fostered by requiring each student to individually take the posttest. Positive interdependence was established by having the students share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

Two versions of *Designing Controlled Experiments* were developed for this study. The introductory material, instructional content, and practice problems were exactly the same in the two versions. However, one version (cued) included explicit group member interaction cues embedded throughout the program while the other (noncued) did not include these cues. The cued interaction version included two types of group member interaction cues. One type of cue was presented immediately preceding the practice problems for each lesson. These were content summary cues. The other type of interaction cues were presented along with certain examples throughout the program. These were explaining cues.

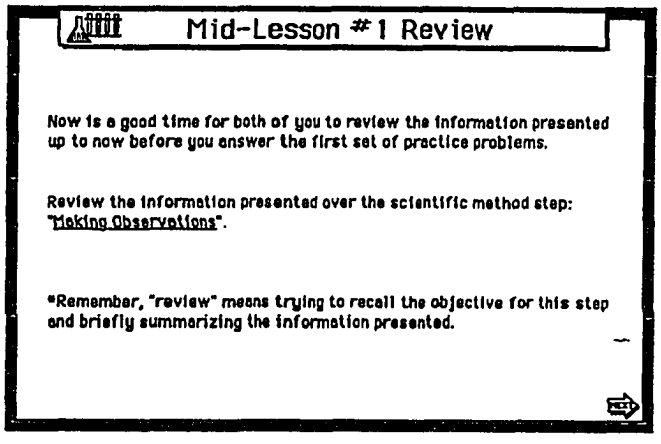
The content summary cues were similar to the cues or scripts found in the systematic interaction and processing strategy developed by Dansereau (1985). These cues assigned the summarizer or explainer role to one group member and the listener role to the other group member. The summarizer was directed by name to recall the objectives and summarize the information presented in the lesson. The listener was directed by name to listen carefully and ask questions about things that were unclear, omitted, or in error. The summarizer and listener roles alternated between dyad members two or three times before each set of practice problems. The program assigned each student participating in the cued version of the program the role of summarizer six times, the role of explainer two times, and the role of listener eight times throughout the entire three-lesson program.

The noncued version of the program prompted group members to review the information with each other before proceeding to the practice problems. The program also reminded the students that "Reviewing includes recalling the objectives and summarizing the information presented." The only differences between the cued version and the noncued version was the cueing of roles and the specific directions for carrying out these roles. Figure 1 illustrates the differences between the cued and noncued versions for a typical summary screen.

The second type of cues used in the cued version were explaining cues. These cues directed one student to verbally explain an example, while the other student listened. As with the content summary cues, the listener was told to "Listen carefully and ask questions about things you don't agree with, including errors or missing pieces of information." In the noncued version, the program simply prompted students to explain an example. No roles were either assigned



Summary screen: Cued Version



Summary screen: Noncued Version

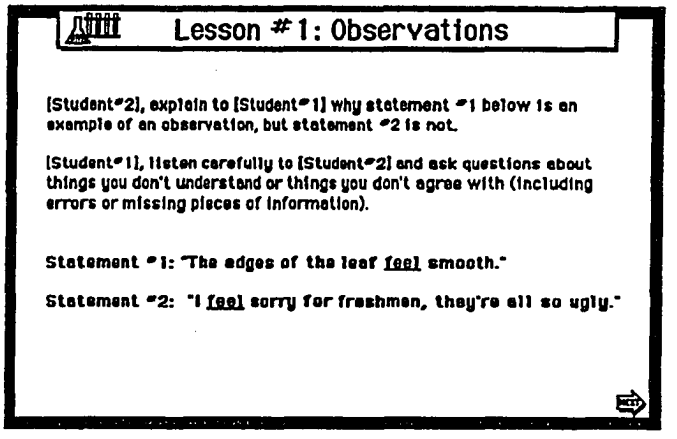
Figure 1. Sample summary screens in the cued and noncued versions.

or explained. Figure 2 illustrates the differences between the cued and noncued versions in a typical explanation screen.

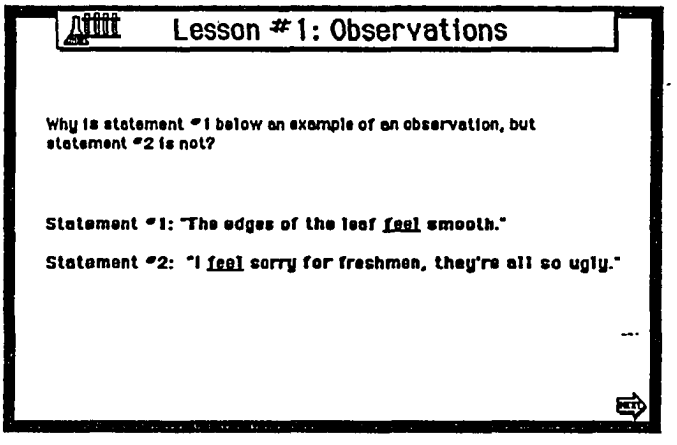
Both the content summary and explaining cues prompted the students to verbally interact with their partner. The noncued version of the program provided the same opportunities for students to interact, but the program did not explicitly prompt the students to do so. All instances of interaction cues are displayed in Appendix B. The corresponding screens for the noncued version of the program are printed beneath each cued screen as well. Each screen of the entire cued version of the program is presented in Appendix C.

Procedure

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



Explanation screen: Cued Version



Explanation screen: Noncued Version

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

All dyads were then randomly assigned to either the cued or noncued versions of the program. There were a total of 256 students (128 dyads) at the beginning of the study. Data from 25 students were unusable due to absences or severe behavior problems during the study.

All the students participating in this study had experienced at least 2 months of working in formal and informal cooperative learning groups. The general science program at the junior high school emphasized cooperative group work using the Circles of Learning model of cooperative learning (Johnson et al., 1990). Students had been taught and evaluated on such essential collaborative skills as using each other's first names, staying with assigned groups, remaining on task, and carrying out assigned roles during laboratory activities. Students also had some experience participating in roles such as summarizer, listener, and explainer. The students had experience with various reward interdependence structures, including group grades for laboratory reports, projects, and homework assignments. Making individuals within cooperative groups responsible for specific materials and resources was also a strategy emphasized in the eighth-grade science program.

All dyads were given three 55-minute class periods on 3 consecutive days to complete the program. Each dyad was given the first class period to complete the introduction and Lesson One, another class period on the second day to complete Lesson Two, and one final class period on the third day to complete Lesson Three. An attitude survey followed by a posttest was administered on the fourth day of the study.

Eight to twelve dyads moved from their regular science classroom to a large computer room to work on the CBI program at one time. The students were informed that the program presented important information necessary for

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

Before sitting down at the computer on the first day of the program, each member of the dyads was randomly assigned "Student #1" or "Student #2." When the dyads began either version of the program, each member individually typed their name into the "Student #1" or "Student #2" fields. Each dyad worked at its own pace throughout a 55-minute class period. Students in dyads finishing early on any of the 3 days were sent back to their regular science class without proceeding to the next lesson. Each member of every dyad individually completed the attitude survey and a written posttest on the fourth day.

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

Dependent Measures

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

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

A written posttest was administered on the day following the completion of the computer program. This 28-item test included labeling, multiple-choice, and constructed-response questions similar to the practice problems presented in the CBI program. Fifteen posttest items measured student knowledge of the content covered in the program. The knowledge items represented performances requiring the learner to state or identify concrete or defined concepts. Thirteen posttest items measured students' ability to apply what they learned from the program. The application items represented performances requiring the learner to apply rules to identify instances of concepts or to solve problems (see Gagné, 1985). The KR-21 reliability test of this posttest was .87.

A copy of the posttest is found in Appendix D. Each item was worth one point, with the exception of two of the application items which were worth two points each. There were a total of 15 knowledge-item points, and 15 application-item points. All posttests were scored by the researcher using the key displayed in Appendix D. Posttest performance represented an individual measure.

A ten item Likert-scale attitude survey was administered prior to the posttest. The items measured student interest, motivation, confidence, enjoyment, and attitudes toward working with a partner. The Cronbach Alpha reliability of this attitude survey was .78. The complete attitude survey can be found in Appendix E. Student attitude represented an individual measure.

Other Measures

Other measures in this study included time data recorded by the computer, and interaction behavior as recorded by a video camera and tape recorder.

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

Interaction behavior was evaluated by the researcher while examining videotapes of a sample of students participating in the program. Students from six dyads in each of the six treatment groups were randomly selected to be videotaped. Nine different types of interaction behaviors were recorded and tabulated from the videotaped observations. These observations were made only when students were viewing the interaction screens during one lesson. Equal numbers of dyads from all six treatment groups were observed. Separate observations were recorded for each individual within every sample dyad.

Appendix F includes the observation sheet used to record the different types of student behavior during the interaction screens. Nine different categories of behavior were used. Some of these categories represented those behaviors addressed in the cues, including summarizing, explaining, asking for

help, and identifying errors. Other categories represented behaviors that were not specifically addressed in the cues, but they contributed to one partner helping the other understand the material. These helping behaviors included giving solicited and unsolicited help, checking for understanding, and offering verbal encouragement. In addition, any incidents of students being off-task during the interaction screens were recorded. Off-task behavior included talking to members of other dyads, talking to partners about things unrelated to the program, leaving the computer, looking at students from other dyads for sustained periods of time while the other partner read the screens and moved on, and reading or writing material unrelated to the program.

Design and Data Analysis

This study was a posttest-only control group design. It was a 2 (cued interactions versus noncued interactions) by 3 (lower-ability dyads, higher-ability dyads, and mixed-ability dyads) factorial design. Both the cueing and grouping variables were between-subjects variables.

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

The observation data on group member interaction were analyzed using chi-square tests of significance for total cued behaviors, total helping behaviors, and total off-task behaviors.

CHAPTER III

RESULTS

The results are reported below within five main categories. These categories include posttest performance, attitudes, practice problem performance, time, and interaction behavior recorded on videotape from a sample of 72 students within 36 dyads.

Posttest Performance

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

Table 2 provides an analysis of variance (ANOVA) summary table for performance scores. ANOVA indicated that subjects who used the cued version of the program performed significantly better on the posttest than those who used the noncued version, $F(1, 225) = 12.97$, $p < .001$. ANOVA also indicated a significant performance difference between subjects in the three ability groupings, $F(2, 225) = 45.92$, $p < .001$. Post hoc analyses using Tukey HSD

Table 1

Means and Standard Deviations for Posttest Performance by Version and Ability Grouping

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

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

[a]30 possible posttest points, minimum score = 5, maximum score = 30.

Table 2

ANOVA Summary Table for Individual Posttest Performance Scores

Source	SS	DF	MS	F-Ratio	P
Version	389.53	1	389.53	12.97	.000
Ability Grouping	2758.78	2	1379.39	45.92	.000
Version by Ability Grouping	3.03	2	1.52	0.05	.950
Error	6758.15	225	30.04		

pairwise comparisons revealed that the mean performance scores between each of the three ability groupings were significantly different ($p < .001$). Subjects assigned to higher-ability dyads performed significantly better than those in the mixed dyads and those in the lower-ability dyads. In addition, subjects in the mixed dyads performed significantly better than those in the lower-ability dyads. ANOVA did not indicate a significant interaction between version and ability grouping when individual performance scores were analyzed.

The posttest scores of lower and higher-ability students were analyzed separately to determine the effect of homogeneous versus heterogeneous grouping on performance. Table 3 reveals that the mean posttest score was 15.51 ($SD = 4.62$) for lower-ability students in homogeneous dyads and 14.85 ($SD = 4.33$) for lower-ability students in heterogeneous dyads. The mean posttest score was 23.92 ($SD = 5.63$) for higher-ability students in homogeneous dyads and 22.46 ($SD = 5.87$) for higher-ability students in heterogeneous dyads.

Separate 2 (version) by 2 (grouping) ANOVAs were conducted on the posttest scores of lower and higher-ability students. Table 4 provides an ANOVA summary table for the lower-ability students' posttest scores. ANOVA indicated that lower-ability students who used the cued version performed significantly better on the posttest ($M = 16.49$, $SD = 4.83$) than lower-ability students who used the noncued version ($M = 14.05$, $SD = 3.84$), $F(1,113) = 7.01$, $p < .01$. However, ANOVA did not reveal a significant difference between students in the homogeneous and heterogeneous dyads for lower-ability students or significant interaction effects between version and grouping. Table 5 provides an ANOVA summary table for the higher-ability students' posttest scores. This ANOVA indicated that higher-ability students who used the cued version performed significantly better on the posttest

Table 3

Posttest Means and Standard Deviations for Lower and Higher-Ability Students

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

Note. "Homogeneous" indicates both members of each dyad were from the same ability group, and "heterogeneous" indicates one member of the dyad was lower-ability while the other member was higher-ability.

Table 4

ANOVA Summary Table for Lower-Ability Students' Posttest Scores

Source	SS	DF	MS	F-Ratio	P
Version	134.96	1	134.96	7.01	.009
Grouping	8.19	1	8.19	0.43	.516
Version by Grouping	5.98	1	5.98	0.31	.578
Error	2175.69	113	19.25		

Table 5

ANOVA Summary Table for Higher-Ability Students' Posttest Scores

Source	SS	DF	MS	F-Ratio	P
Version	184.57	1	184.57	5.90	.017
Grouping	50.75	1	50.75	1.62	.206
Version by Grouping	0.22	1	0.22	0.01	.933
Error	3443.42	110	31.30		

(M = 24.79, SD = 5.36) than the higher-ability students who used the noncued version (M = 22.05, SD = 5.81), $F(1,110) = 5.90$, $p < .05$. ANOVA did not reveal a significant difference between higher-ability students in the homogeneous and heterogeneous dyads or significant interaction effects between version and grouping.

In addition to individual posttest performance, differences between the posttest scores of partners in each dyad were calculated and analyzed. Means and standard deviations for posttest score differences are reported in Table 6. These data reveal that the mean posttest score difference was 6.70 (SD = 5.17) for partners who used the cued version of the CBI program and 5.84 (SD = 5.05) for those who used the noncued version. Table 6 also shows that the mean posttest score difference was 5.84 (SD = 4.72) for partners in the lower-ability dyads, 8.13 (SD = 5.47) for those in the mixed-ability dyads, and 4.81 (SD = 4.61) for those in the higher-ability dyads.

Table 7 provides an ANOVA summary table for posttest differences between dyad members. ANOVA indicated a significant main effect for ability grouping, $F(2, 106) = 4.45$, $p < .05$. Post hoc analyses using Tukey HSD pairwise comparisons revealed that the only significant difference in the mean performance scores of the three different ability groups was between the mixed-ability dyads and the higher-ability ($p < .05$). ANOVA did not indicate a significant main effect for version or a significant interaction between version and ability grouping when posttest differences were analyzed.

Attitudes

Means and standard deviations for the individual attitude survey are reported in Table 8. The numbers represent Likert-scale responses ranging from 1 (strongly agree) to 4 (strongly disagree). These data indicated that the students

Table 6

Differences in Posttest Scores Between Dyad Members by Version and Ability Grouping

	Ability Grouping			
Version	LL	LH	HH	Total
Cued	6.55 (4.57) n = 20	8.22 (5.74) n = 18	5.42 (5.09) n = 19	6.70 (5.17) n = 57
Noncued	5.00 (4.90) n = 17	8.05 (5.37) n = 20	4.17 (4.09) n = 18	5.84 (5.05) n = 55
Total	5.84 (4.72) n = 37	8.13 (5.47) n = 38	4.81 (4.61) n = 37	6.28 (5.11) N = 112

Note. Each "n" represents the number of dyads per cell.
LL = Homogeneous lower-ability dyads, LH = heterogeneous (mixed-ability) dyads, HH = homogeneous higher-ability dyads.

Table 7

ANOVA Summary Table for Differences in Posttest Scores Between Dyad Members

Source	SS	DF	MS	F-Ratio	P
Version	27.47	1	27.47	1.10	.296
Ability Grouping	221.50	2	110.75	4.45	.014
Version by Ability Grouping	9.89	2	4.93	0.20	.821
Error	2638.14	106	24.89		

Table 8

Attitude Survey Responses by Version

Attitude Survey Item	Version		
	Cued	Noncued	Total
1. The computer program was interesting.	2.22 (0.77)	2.26 (0.71)	2.24 (0.74)
2. I tried hard to understand the information presented in the computer program.	1.95 (0.68)	1.83 (0.69)	1.89 (0.69)
3. My partner tried hard to understand the information presented in the program.	2.10 (0.87)	2.03 (0.88)	2.06 (0.87)
4. I concentrated on learning throughout the entire program.	2.14 (0.73)	2.00 (0.75)	2.07 (0.74)
5. My partner concentrated on learning throughout the entire program.	2.10 (0.75)	2.11 (0.82)	2.10 (0.78)
6. The information presented in this program was easy to understand.	2.28 (0.78)	2.36 (0.85)	2.32 (0.82)
7. I enjoyed working with a partner.	1.91 (0.97)	1.85 (0.93)	1.88 (0.95)
8. I am confident that I will do well on the final test.	2.22 (0.71)	2.29 (0.87)	2.25 (0.79)
9. I would like to learn more about designing experiments.	2.44 (0.82)	2.65 (0.74)	2.54 (0.79)
10. I would like to work with a partner again and do another science lesson on the computer.	1.82 (0.88)	1.90 (0.93)	1.86 (0.91)

Note. Responses ranged from 1 (strongly agree) to 4 (strongly disagree). Standard deviations in parentheses.

generally enjoyed working with a partner (M = 1.88, SD = 0.95) and wanted to work with a partner again to do another science lesson on the computer (M = 1.82, SD = 0.91). Most students also reported that they tried hard to understand the information presented in the computer program (M = 1.89, SD = 0.69). However, many students did not feel the information was easy to understand (M = 2.32, SD = 0.82). Students also responded negatively to the continuing motivation statement about wanting to learn more about designing experiments (M = 2.54, SD = 0.79).

All ten attitude survey items were analyzed using MANOVA. This analysis indicated no significant differences in overall, collective responses by version, $F(10, 214) = 1.36$, $p > .05$, or ability grouping, $F(20, 428) = 1.34$, $p > .05$.

Practice Performance

Means and standard deviations for practice performance are reported in Table 9. These data reveal that the mean practice score was 18.36 (SD = 4.98) for dyads who used the cued version of the CBI program and 16.17 (SD = 5.78) for those who used the noncued version. Table 9 also shows that the lower-ability dyads had a mean practice score of 13.13 (SD = 4.98), the mixed-ability dyads averaged 18.42 (SD = 5.06), and the higher-ability dyads averaged 20.25 (SD = 3.69) for practice performance.

Table 10 provides an ANOVA summary table for practice performance. ANOVA indicated that dyads who used the cued version performed significantly better on the practice items than those who used the noncued version, $F(1, 106) = 6.50$, $p < .01$. ANOVA also indicated a significant effect due to ability grouping, $F(2, 106)=24.59$, $p < .001$. Tukey HSD post hoc analysis of practice scores revealed that the lower-ability dyads performed significantly worse on the practice items than either the mixed-ability dyads or higher-ability dyads

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

Time

The total time spent using the program is reported in Table 11 by version and ability grouping. These data reveal that the average amount of time spent on the computer program was 83.7 minutes for dyads assigned to the cued version and 78.0 minutes for dyads assigned to the noncued version. The lower-ability dyads averaged 81.4 minutes, the mixed-ability dyads averaged 84.0 minutes, and the higher-ability dyads averaged 77.5 minutes on the program.

Table 11 also reports the amount of time spent on the instruction, interaction, and practice screens. These data indicate that dyads who received the cued version of the program spent an average 51.8 minutes on the instruction screens, 7.8 minutes on the interaction screens, and 24.4 minutes on practice screens. Dyads who received the noncued version spent 47.5 minutes, 5.1 minutes, and 23.8 minutes on these sections respectively. The lower-ability dyads averaged 53.0 minutes on the instruction screens, 6.2 minutes on the interaction screens, and 21.6 minutes on practice screens. Mixed-ability dyads spent 50.7 minutes, 6.7 minutes, and 25.6 minutes, while the higher-ability dyads spent 45.6 minutes, 6.7 minutes, and 25.0 minutes on these sections respectively.

Table 9

Means and Standard Deviations for Practice Performance by Version and Ability Grouping

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

Note. Each "n" represents the number of dyads in each cell. There were 27 possible practice item points. Standard deviations are in parentheses. LL = Homogeneous lower-ability dyads, LH = heterogeneous (mixed-ability) dyads, HH = homogeneous higher-ability dyads.

Table 10

ANOVA Summary Table for Practice Performance

Source	SS	DF	MS	F-Ratio	P
Version	133.21	1	133.21	6.50	.012
Ability Grouping	1008.51	2	504.25	24.59	.000
Version by Ability Grouping	23.11	2	11.56	0.56	.571
Error	2173.73	106	20.51		

Table 11

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

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

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

Table 12 provides an ANOVA summary table for total program time. ANOVA indicated that dyads assigned to the cued version spent significantly more time using the program than dyads assigned to the noncued program, $F(1, 102) = 3.89$, $p < .05$. Differences in total time between the three different ability groups were not significant.

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

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

Table 12

ANOVA Summary Table for Total Time by Version and Ability Grouping

Source	SS	DF	MS	F-Ratio	P
Version	3295553.42	1	3295553.42	3.89	.050
Ability Grouping	2932871.47	2	1466435.73	1.73	.183
Version by Ability Grouping	1595784.71	2	797892.35	0.94	.394
Error	86490378.58	102	847944.89		

Interaction Behaviors

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

The cued behaviors represented those behaviors specifically addressed by the cues directed at each dyad member during the summary and explanation screens. These behaviors included summarizing, explaining, identifying errors, and asking for help when needed. Table 13 presents the total number of instances recorded for students in the sample dyads for each of the cued behaviors. These data reveal that students in the cued version exhibited a total of 101 cued behaviors, while students in the noncued version exhibited 44 cued behaviors. A chi-square test performed on total cued behaviors by version indicated that this difference was significant, X^2 (1, N = 72) = 22.4, p < .001. Table 13 also indicates differences between the two versions for specific types of cued behaviors. Subjects in the dyads who used the cued version of the program summarized a total of 46 times, while subjects in the 18 dyads who used the noncued version summarized 12 times. Subjects in the dyads who used the cued version explained 32 times compared to 27 times for subjects in the noncued dyads. There were three instances of identifying errors for subjects in the cued dyads, while no instances were observed for those who used the noncued version. Subjects in dyads who used the cued version asked for help 20 times compared to 5 for those who used the noncued version.

Table 13

Instances of Interaction Behaviors for Sample Dyads by Version

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

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

Table 13 also reports the instances of helping behaviors observed for members of the sample dyads. These behaviors were not specifically cued by the computer program; they included giving solicited help, giving unsolicited help, checking for partner understanding, and encouraging partner. These data reveal that students in the cued version exhibited a total of 48 helping behaviors, while students in the noncued version exhibited seven helping behaviors. A chi-square test performed on total helping behaviors by version indicated that this difference was significant, X^2 (1, $\underline{N}$ = 72) = 28.6, $\underline{p} < .001$. Table 13 also reports instances of each type of helping behavior by version. These data reveal that subjects in the cued dyads gave solicited help 14 times and unsolicited help 12 times. No instances of solicited help and three instances of unsolicited help were observed for subjects in the dyads who used the noncued version. Subjects in the dyads who used the cued version of the program checked for understanding seven times, while those who used the noncued version checked for understanding two times. Subjects in the cued dyads encouraged their partner 15 times while those in the noncued dyads encouraged their partners two times.

The third category of recorded interactions was off-task behavior. Table 13 also reports the instances of observed off-task behavior for subjects in the sample of dyads. These data reveal that subjects in dyads who used the cued version of the program were off-task 11 times, while those who used the noncued version were off-task nine times. A chi-square test indicated that this difference was not significant. However, there was a significant difference in number of off-task behaviors between ability groups, X^2 (2, $\underline{N}$ = 72) = 7.01, $\underline{p} < .05$. Subjects in the lower-ability dyads were off-task 10 times, subjects in the mixed-ability dyads were off-task nine times, and subjects in the higher-ability dyads were off-task one time during the interaction screens.

CHAPTER IV

DISCUSSION

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

Results for performance indicated that students who used the cued version of the program performed significantly better on the posttest than students who used the noncued version. Furthermore, separate analyses for each ability group indicated that lower-ability students who used the cued version performed better on the posttest than lower-ability students who used the noncued version and higher-ability students who used the cued version performed better than higher-ability students who used the noncued version. In addition to better posttest performance, students using the cued version of the

program also performed significantly better on the practice items than students using the noncued version of the program.

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

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

Because students who used the cued version did summarize information before answering practice problems, it is not surprising that these students learned more from the program than students who used the noncued version. Summarizing information presented in an instructional program is one of the effective elements of instruction (Gagné, 1985; Hunter, 1982). Although all

students in this study were instructed to summarize when needed, the cues provided the direction and reminders necessary for consistent interaction between group members.

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

Examining posttest performance by ability across versions yielded few surprises. Students assigned to higher-ability dyads performed significantly better on the posttest than students assigned to mixed-ability dyads. Both these groups performed significantly better on the posttest than students assigned to the lower-ability dyads. These results show that ability, as measured by

performance on a nationally standardized test, is a very strong predictor of performance when students work together during a CBI program.

The differences between the posttest scores of dyads in the three different ability grouping categories were also not surprising. Partners in the mixed-ability dyads had a mean difference of over eight points, compared to less than five between members of the higher-ability dyads and less than six for members of the lower-ability dyads. These results were consistent across versions, again illustrating the major effect that general academic ability has on learning from an instructional program.

An interesting result to emerge for ability was the lack of significant differences in posttest scores between heterogeneously and homogeneously grouped students from the same ability group. Contrary to the results from other cooperative learning studies that examined ability grouping, the higher-ability students in the current study did not perform significantly worse when paired with a lower-ability student than when paired with a higher-ability student. By the same token, lower-ability students performed at nearly the same level when paired with either a higher-ability student or a lower-ability student. These results do not support the results of studies conducted by Beane and Lemke (1971), who concluded that mixed-ability grouping was beneficial for high-ability students but not for low-ability students. In other related studies, Hooper and Hannafin (1988, 1991), and Hooper (1992) found that homogeneous grouping was more effective than heterogeneous grouping for high-ability students, but heterogeneous grouping was more effective than homogeneous grouping for low-ability students.

However, in most of the previous studies investigating the effects of ability grouping on achievement, the average-ability students were either eliminated from the subject pool (e.g. Hooper & Hannafin, 1988, 1991) or classified into separate, average-ability groups (e.g. Webb, 1982; Yager et al., 1985). The present study used a median split procedure for determining lower and higher-ability students. Consequently, some students near the median may have been classified as lower-ability while others, with only slightly higher ITBS scores, were classified as higher-ability. It is possible that the presence of average ability in this study "watered down" any effects attributable to high versus low ability.

The results from a number of en route measures examined by ability grouping create an interesting picture of the learning behaviors of students assigned to the different ability groups. Students in the lower-ability dyads performed significantly worse on the practice items than students in either the mixed-ability dyads or higher-ability dyads. It appears that having a higher-ability student in the group increased practice performance, regardless of whether the higher-ability student was paired with a lower or higher-ability student. This may indicate that the higher-ability students in the mixed-ability dyads were more responsible for answering the practice problems than their lower-ability partners.

The time data for the three different ability groups also indicate some typical learning behavior patterns. The higher-ability dyads spent significantly less time on the instruction screens than either the heterogeneous groups or the homogeneous lower-ability groups. This was probably due to the reading levels of the higher-ability students. These students most likely read through the information presented during the information screens more quickly than the

lower-ability students. Although students in higher-ability dyads spent less time on the information screens than students in the other dyads, they spent significantly more time on the practice screens. This suggests students in the higher-ability dyads discussed the practice items more thoroughly than students in mixed or lower-ability dyads before selecting answers.

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

In examining student attitudes, the results showed no significant differences by version or ability grouping. This may seem surprising, since other researchers have reported that attitudes are influenced by cooperative learning (Hooper et al., 1993; Mevarech, et al., 1987). However, these studies compared cooperative learning to individual learning, while in the current study all students worked with a partner at the computers. Results for attitudes did indicate that most students enjoyed working with a partner, wanted to work with a partner again, and tried hard to understand the information. Students also reported that they did not feel the information was easy to understand and they did not want to learn more about the subject matter. These negative responses were probably due to the difficult nature of the material presented.

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

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

The results from this study also suggest several specific areas for future research. Although the cues differentially affected the number of times students summarized, students who used both versions interacted approximately the

same number of times during the explanation screens. These explanation screens offered more specific direction to the students by asking questions to be answered. Perhaps a more directed approach to the summary screens through the use of questioning strategies would have yielded higher participation during these screens. Also, the cues used in this study called on students by name. It is not certain how this small amount of personalization may have influenced the students' experience with the program. Future research could investigate the effects of personalization within cooperative learning groups. Another area of future research deals with the manner in which students were grouped by ability in this study. The results may have turned out differently had low, medium, and high ability groups been established. Conducting similar research using three different ability groups may yield data more useful to those interested in ability as an important research and design variable.

There may also be some value in investigating the effects of summary and explanation cues for individuals versus groups. The effects of structuring verbal interaction may become even more clear if groups are compared to individuals who are prompted to summarize and explain to themselves throughout an instructional program. Research of this nature may help determine the best possible way to develop CBI programs for individuals as well as cooperative learning groups.

As the number of teachers utilizing technology to deliver instruction increases, more students will be required to work in small groups to learn from computer-based instruction. Instructional designers should continue to determine which variables will influence learning when students use CBI in cooperative settings. As more information is gathered about how to design

instruction for small groups, a clearer picture may emerge about the appropriate uses of cooperative learning with educational technology.

REFERENCES

Beane, W. E., & Lemke, E. A. (1971). Group variables influencing the transfer of conceptual behavior. Journal of Educational Psychology, 62, 215-218.

Becker, H. J. (1991). How computers are used in schools: Basic data from the 1989 I.E.A. computers in education survey. Journal of Educational Computing Research, 7(4), 385-406.

Carrier, C. A., & Sales, G. C. (1987). Paired versus individual work on the acquisition of concepts in a computer-based instructional lesson. Journal of Computer-Based Instruction, 14, 11-17.

Cohen, E. G. (1992). Restructuring the classroom: Conditions for productive small groups (Contract No. R117Q00005-91). Madison, WI: Wisconson Center for Educational Research. (ERIC Document Reproduction Service No. ED 347 639)

Cosden, M. A. (1989). Cooperative groups and microcomputer instruction: Combining technologies. The Pointer, 33(2), 21-26.

Dalton, D. W., Hannafin, M. J., & Hooper, S. (1989). The effects of individual versus cooperative computer-assisted instruction on student performance and attitudes. Educational Technology Research and Development, 37(2), 15-24.

Dansereau, D. F. (1985). Learning strategy research. In J. W. Segal, S. F. Chipman, & R. Glaser (Eds.), Thinking and learning skills: Vol. 1. Relating instruction to research (pp. 209-239). Hillsdale, NJ: Erlbaum.

Deutsch, M. (1949). An experimental study of the effects of cooperation and competition upon group processes. Human Relations, 2, 199-232.

Fletcher, B. (1985). Group and individual learning of junior high school children on a micro-computer-based task. Educational Review, 37, 252-261.

Gagné, R. M. (1985). The conditions of learning. San Francisco, CA: Holt, Rinehart, and Winston, Inc.

Gagné, R. M., & Smith, E. C. (1962). A study of the effects of verbalization on problem solving. Journal of Experimental Psychology, 29, 12-18.

Hooper, S. (1992). Effects of peer interaction during computer-based mathematics instruction. Journal of Educational Research, 85(3), 180-189.

Hooper, S., & Hannafin, M. J. (1988). Cooperative CBI: The effects of heterogeneous versus homogeneous grouping on the learning of progressively complex concepts. Journal of Educational Computing Research, 4, 413-424.

Hooper, S., & Hannafin, M. J. (1991). The effects of group composition on achievement, interaction, and learning efficiency during computer-based cooperative instruction. Educational Technology Research and Development, 39(3), 27-40.

Hooper, S., Temiyakarn, C., & Williams, M. D. (1993). The effects of cooperative learning and learner control on high- and average-ability students. Educational Technology Research and Development, 41(2), 5-18.

Hunter, M. C. (1982). Mastery teaching. El Segundo, CA: TIP Publications.

Johnson, D. W., & Johnson, R. T. (1989). Cooperation and competition: Theory and Research. Edina, MN: Interaction Book Company.

Johnson, D. W., Johnson, R. T., & Holubec, E. J. (1990). Circles of learning: Cooperation in the classroom. Edina, MN: Interaction Book Company.

Johnson, D. W., Maruyama, G., Johnson, R., Nelson, D., & Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. Psychological Bulletin, 89, 47-62.

Johnson, R. T., Johnson, D. W., & Stanne, M. B. (1985). Effects of cooperative, competitive, and individualistic goal structures on computer-assisted instruction. Journal of Educational Psychology, 77, 668-677.

Johnson, R. T., Johnson, D. W., & Stanne, M. B. (1986). Comparison of computer-assisted cooperative, competitive, and individualistic learning. American Educational Research Journal, 23, 382-392.

King, A. (1989). Verbal interaction and problem-solving within computer-assisted cooperative learning groups. Journal of Educational Computing Research, 5(1), 1-15.

Lambiotte, J. G., Dansereau, D. F., O'Donnell, A. M., Young, M. D., Skaggs, L. P., Hall, R. H., & Rocklin, T. R. (1987). Manipulating cooperative scripts for teaching and learning. Journal of Educational Psychology, 79(4), 424-430.

Makuch, J. R., Robillard, P. D., & Yoder, E. P. (1992). Effects of individual versus paired/cooperative computer-assisted instruction on the effectiveness and efficiency of an in-service training lesson. Journal of Educational Technology Systems, 20(3), 199-208.

McDonald, B. A., Larson, C. O., Dansereau, D. F., & Spurlin, J. E. (1985). Cooperative dyads: Impact on text learning and transfer. Contemporary Educational Psychology, 10, 369-377.

Mevarech, Z. R., Silber, O., & Fine, D. (1991). Learning with computers in small groups: Cognitive and affective outcomes. Journal of Educational Computing Research, 7(2), 233-243.

Mevarech, Z. R., Stern, D., & Levita, I. (1987). To cooperate or not to cooperate in CAI: That is the question. Journal of Educational Research, 80, 164-167.

O'Donnell, A. M., Dansereau, D. F., Hall, R. H., & Rocklin, T. R. (1987). Cognitive, social/affective, and metacognitive outcomes of scripted cooperative learning. Journal of Educational Psychology, 79(4), 431-437.

O'Donnell, A. M., Rocklin, T. R., Dansereau, D. F., Hythecker, V. I., Young, M. D., & Lambiotte, J. G. (1987). Amount and accuracy of information recalled by cooperative dyads: The effects of summary type and alternation of roles. Contemporary Educational Psychology, 12, 386-394.

Sharan, S., & Sharan, Y. (1976). Small-group Teaching. Englewood Cliffs, N. J.: Educational Technology Publications.

Slavin, R. (1980). Cooperative learning. Review of Educational Research, 50, 315-342.

Slavin, R. (1983). Cooperative learning. New York: Longman.

Slavin, R. (1993). Ability grouping in the middle grades: Achievement effects and alternatives. Elementary School Journal, 93(5), 535-552.

Trowbridge, D., & Durnin, R. (1984). Results from an investigation of groups working at the computer. Washington, DC: The National Science Foundation.

Webb, N. M. (1982). Group composition, group interaction, and achievement in small cooperative groups. Journal of Educational Psychology, 74, 642-655.

Webb, N. M. (1989). Peer interaction and learning in small groups. International Journal of Educational Research, 13(1), 21-39.

Whyte, M. M., Knirk, F. G., Casey, R. J., & Willard, M. L. (1991). Individualistic versus paired/cooperative computer-assisted instruction: Matching instructional method with cognitive style. Journal of Educational Technology Systems, 19(4), 299-312.

Yager, S., Johnson, D. W., & Johnson, R. T. (1985). Oral discussion, group-to-individual transfer, and achievement in cooperative learning groups. Journal of Educational Psychology, 77(1), 60-66.

APPENDIX A

"DESIGNING CONTROLLED EXPERIMENTS"
COMPUTER PROGRAM OBJECTIVES

Objectives for "Designing Controlled Experiments"

Knowledge Outcomes

Identify the definitions of the terms Observation, Problem, Hypothesis, and Experiment. (Lesson 1)

Given a list of statements, identify each as either an observation, a problem, a hypothesis, a prediction, or a conclusion. (Lesson 1)

Application Outcomes

Identify the independent and dependent variables stated in given hypotheses. (Lesson 2)

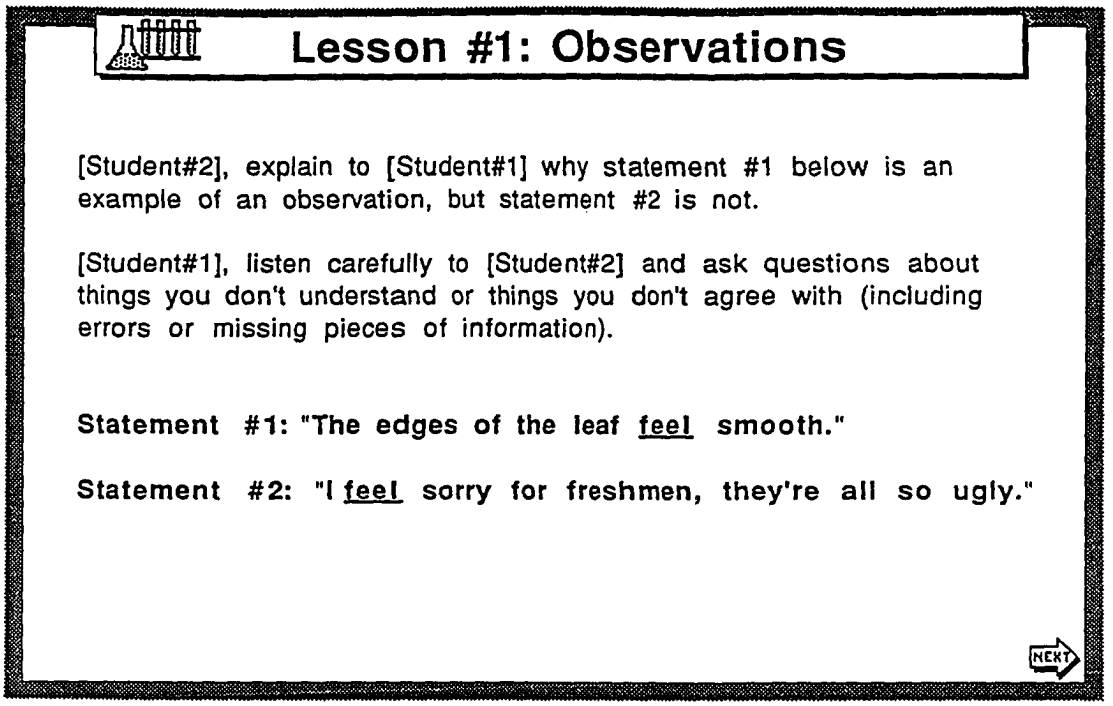
Given an example of two set-ups for an experiment, identify the control and variable groups. (Lesson 2)

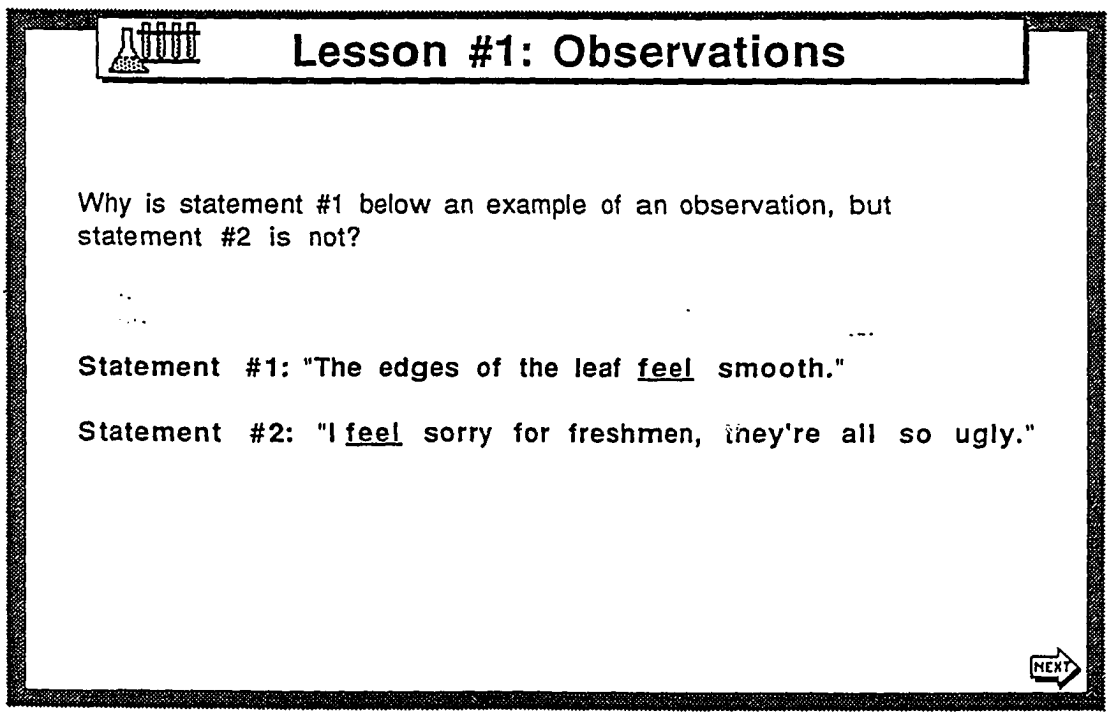
Given descriptions of an experiment's control and variable groups, identify the independent, dependent, and extraneous variables. (Lesson 2)

Given a problem, hypothesis, and prediction statement, design a controlled experiment by generating, listing, and classifying each variable type for a control and variable group. (Lesson 3)

APPENDIX B

CUED VERSUS NONCUED INTERACTION SCREENS





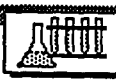
Note. Cued screen (top) with corresponding noncued screen (bottom).

Mid-Lesson #1 Review

Now is a good time for both of you to review the information presented up to now before you answer the first set of practice problems.

Student#1, you will be the **summarizer**. It is your job to verbally review the information presented over the scientific method step: "Making Observations" for Student#2. Try to recall the objective for this step and briefly summarize the information presented.

Student#2, you will be the **listener**. Listen carefully while Student#1 summarizes the information presented over the scientific method step "Making Observation". As Student#1 summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

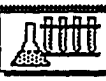


Mid-Lesson #1 Review

Now is a good time for both of you to review the information presented up to now before you answer the first set of practice problems.

Review the information presented over the scientific method step: "Making Observations".

*Remember, "review" means trying to recall the objective for this step and briefly summarizing the information presented.



Mid-Lesson #1 Review

[Student#2], now you will be the **summarizer.** It is your job to verbally review the information presented over the scientific method step: "Identifying a Problem" for [Student#1]. Try to recall the objective for this step and briefly summarize the information presented.

[Student#1], you will be the **listener.** Listen carefully while [Student#2] summarizes the information presented over the scientific method step "Identifying a Problem". As [Student#2] summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

Mid-Lesson #1 Review

Review the information presented over the scientific method step: "Identifying a Problem".

*Remember, "review" means trying to recall the objective for this step and briefly summarizing the information presented.

Mid-Lesson #1 Review

Just one more small summary before you are presented with practice problems.

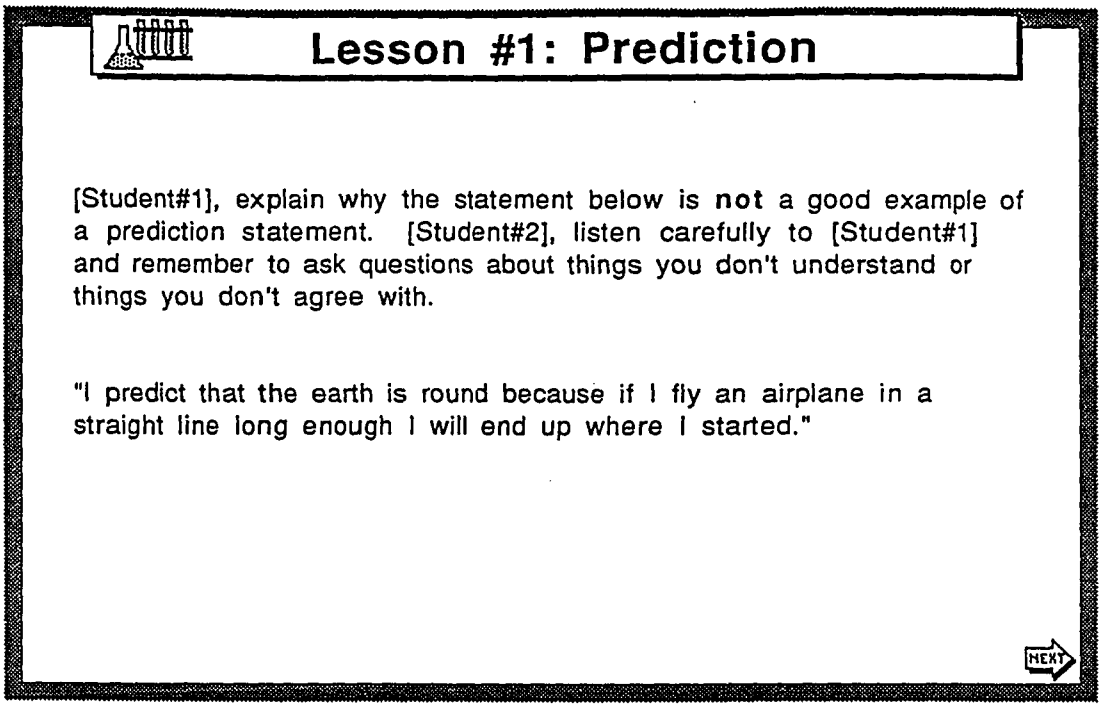
[Student#1], now you will be the **summarizer**. It is your job to verbally review the information presented over the scientific method step: "Choosing a Hypothesis" for [Student#2].

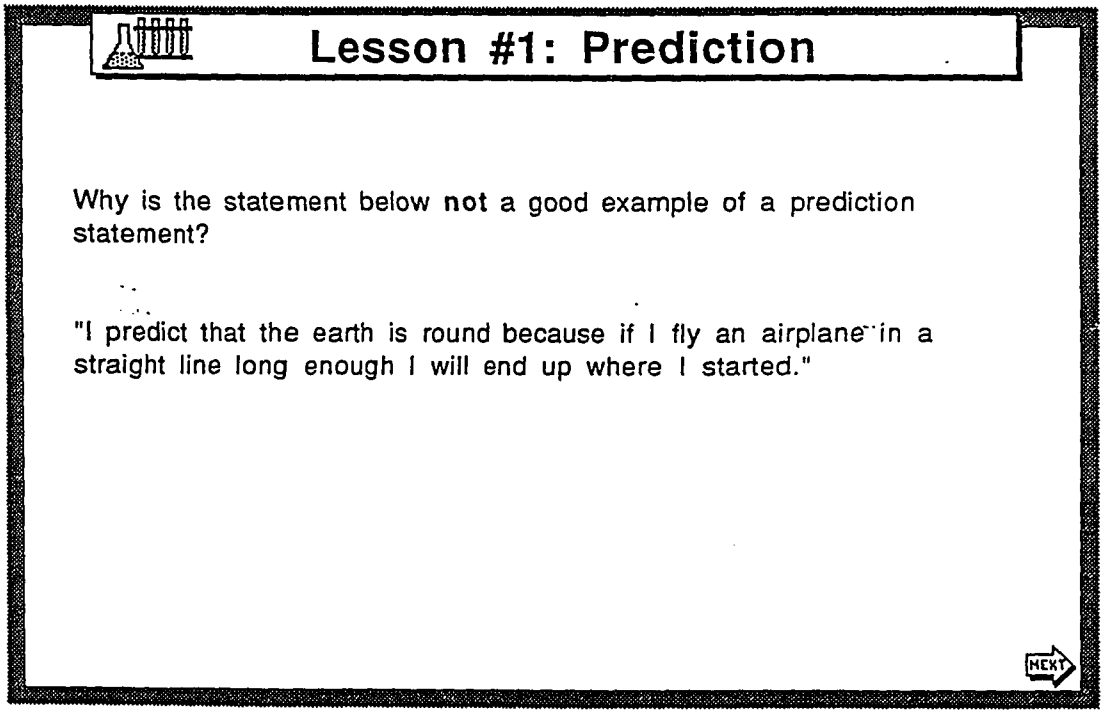
[Student#2], you will be the **listener**. Listen carefully while [Student#1] summarizes the information presented over the scientific method step "Choosing a Hypothesis".

Mid-Lesson #1 Review

Just one more small summary before you are presented with practice problems.

Review the information presented over the scientific method step: "Choosing a Hypothesis".





More Lesson #1 Review

Now is a good time for both of you to review the information presented up to now before you answer the second set of practice problems.

[Student#2], you will be the **summarizer**. It is your job to verbally review the information presented over the scientific method step: "Making a Prediction" for [Student#1]. Try to recall the objective for this step and briefly summarize the information presented.

[Student#1], you will be the **listener**. Listen carefully while [Student#2] summarizes the information presented over the scientific method step "Making a Prediction". As [Student#2] summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

More Lesson #1 Review

Now is a good time for both of you to review the information presented up to now before you answer the second set of practice problems.

Review the information presented over the scientific method step: "Making a Prediction".

*Remember, "review" means trying to recall the objective for this step and briefly summarizing the information presented.

More Lesson #1 Review

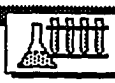
[Student#1], now you will be the **summarizer**. It is your job to verbally review the information presented over the scientific method step: "Designing Experiments" for [Student#2]. Try to recall the objective for this step and briefly summarize the information presented.

[Student#2], you will be the **listener**. Listen carefully while [Student#1] summarizes the information presented over the scientific method step "Making a Prediction". As [Student#1] summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

More Lesson #1 Review

Review the information presented over the scientific method step: "Designing Experiments".

*Remember, "review" means trying to recall the objective for this step and briefly summarizing the information presented.



More Lesson #1 Review

Just one more small summary before you are presented with more practice problems.

[Student#2], now you will be the **summarizer.** It is your job to verbally review the information presented over the scientific method step: "Analyzing Data/Conclusion" for [Student#1].

[Student#1], you will be the **listener.** Listen carefully while [Student#2] summarizes the information presented over the scientific method step "Analyzing Data/Conclusion".

More Lesson #1 Review

Just one more small summary before you are presented with more practice problems.

Review the information presented over the scientific method step: "Analyzing Data/Conclusion".

Lesson #2: Information

[Student#1], explain to [Student#2] why the underlined variable in the hypothesis below is the independent variable, and the non-bolded variable is the dependent variable.

[Student#2], listen carefully to [Student#1]. Be sure to ask questions about things that are unclear or things you think are wrong.

Hypothesis: **The size of the fishtank affects** how big the goldfish will grow.

Click the "next" arrow to check your answers.

Lesson #2: Information

Why is the underlined variable in the hypothesis below the independent variable, and the non-bolded variable the dependent variable?

Hypothesis: **The size of the fishtank affects** how big the goldfish will grow.

Click the "next" arrow to see the answer.

Lesson #2: Information

[Student#2], explain to [Student#1] why the underlined variable in the hypothesis below is the independent variable, and the non-bolded variable is the dependent variable.

[Student#1], listen carefully to [Student#2]. Be sure to ask questions about things that are unclear or things you think are wrong.

Hypothesis: **The amount of cavities in a child's teeth depends on the brand of toothpaste used.**

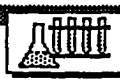
Click the "next" arrow to check your answers.

Lesson #2: Information

Why is the the underlined variable in the hypothesis below the independent variable, and the non-bolded variable the dependent variable?

Hypothesis: **The amount of cavities in a child's teeth depends on the brand of toothpaste used.**

Click the "next" arrow to see the answer.



Mid-Lesson #2 Review

Now is a good time for both of you to review the information presented up to now before you answer the next set of practice problems.

[Student#1], you will be the **summarizer.** It is your job to verbally review the information presented over Independent Variables for [Student#2]. Try to recall the objective for this variable and briefly summarize the information presented.

[Student#2], you will be the **listener.** Listen carefully while [Student#1] summarizes the information presented over Independent Variables. As [Student#1] summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

Mid-Lesson #2 Review

Now is a good time for both of you to review the information presented up to now before you answer the next set of practice problems.

Review the information presented over Independent Variables.

*Remember, "review" means trying to recall the objective for this variable type and briefly summarizing the information presented.

Mid-Lesson #2 Review

[Student#2], now it's your turn to be the **summarizer**. It is your job to verbally review the information presented over Dependent Variables for [Student#1]. Try to recall the objective for this variable and briefly summarize the information presented.

[Student#1], you will be the **listener**. Listen carefully while [Student#2] summarizes the information presented over Dependent Variables. Don't forget to ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

Mid-Lesson #2 Review

Review the information presented over Dependent Variables.

*Remember, "review" means trying to recall the objective for this variable type and briefly summarizing the information presented.

More Lesson #2 Review

Once again it's time for both of you to review the information presented before you answer the next set of practice problems.

[Student#2], you will be the **summarizer.** It is your job to verbally review the information presented over Extraneous Variables for [Student#1]. Try to recall the objective for this and briefly summarize the information presented.

[Student#1], you will be the **listener.** Listen carefully while [Student#2] summarizes the information presented over Extraneous Variables. As [Student#2] summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

More Lesson #2 Review

Once again it's time for both of you to review the information presented before you answer the next set of practice problems.

Review the information presented over Extraneous Variables.

*Remember, "review" means trying to recall the objective for this variable type and briefly summarizing the information presented.

More Lesson #2 Review

[Student#1], now it's your turn to be the **summarizer.** It is your job to verbally review the information presented over Identifying Control and Variable Groups for [Student#2]. Try to recall the objective for this variable and briefly summarize the information presented.

[Student#2], you will be the **listener.** Listen carefully while [Student#1] summarizes the information presented over Identifying Control and Variable Groups. Don't forget to ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

More Lesson #2 Review

Review the information presented over Identifying Control and Variable Groups.

*Remember, "review" means trying to recall the objective for these groups and briefly summarizing the information presented.

Lesson #3 Review

Once again it's time for both of you to review some of the information presented before you answer the next set of practice problems.

[Student#1], you will be the **summarizer.** It is your job to verbally review for [Student#2] the information presented over the first three steps involved in designing controlled experiments: Identifying the Independent and Dependent Variables, Determining the Type of Test, and Determining Three Extraneous Variables. Try to recall the objective for this area and briefly summarize the information presented.

[Student#2], you will be the **listener.** Listen carefully while [Student#1] summarizes the information. As [Student#1] summarizes, ask questions about things you don't understand or things you don't agree with...including errors or missing pieces of information.

Lesson #3 Review

Once again it's time for both of you to review some of the information presented before you answer the next set of practice problems.

Review the information presented over the first three steps involved in designing controlled experiments: Identifying the Independent and Dependent Variables, Determining the Type of Test, and Determining Three Extraneous Variables.

*Remember, "review" means trying to recall the objective for these steps and briefly summarizing the information presented.

Lesson #3 Review

[Student#2], now it is your turn to be the **summarizer**. Summarize for [Student#1] the information presented over the fourth step in designing an experiment: Describe and Label All Variables in the Control and Variable Groups.

[Student#1], **listen** carefully to [Student#2]. Be sure to comment on any errors or missing information.

Click on the "Next" arrow when you are ready for the last set of practice problems.

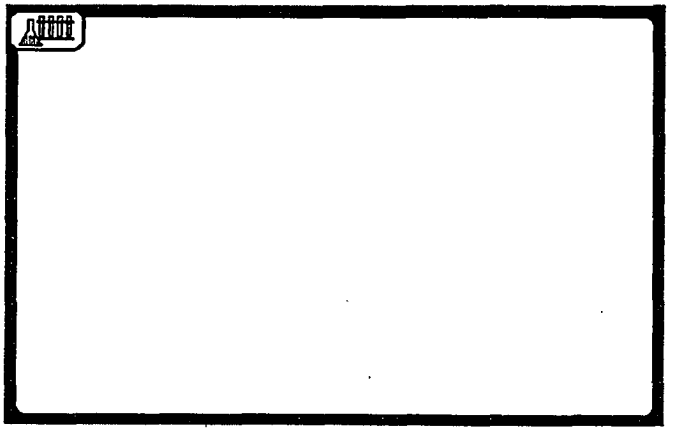
Lesson #3 Review

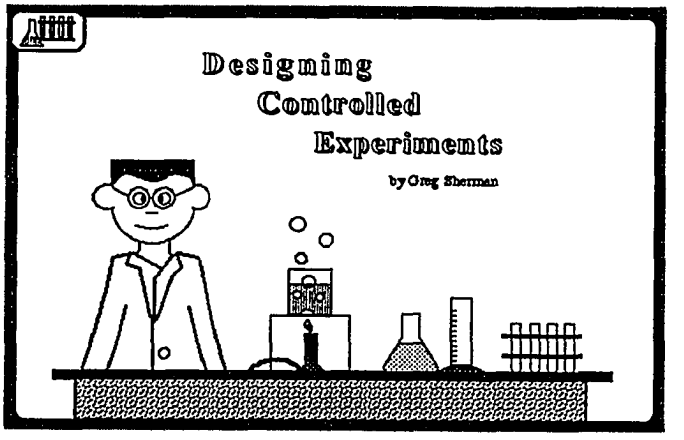
Review the information presented over the fourth step in designing an experiment: Describe and Label All Variables in the Control and Variable Groups.

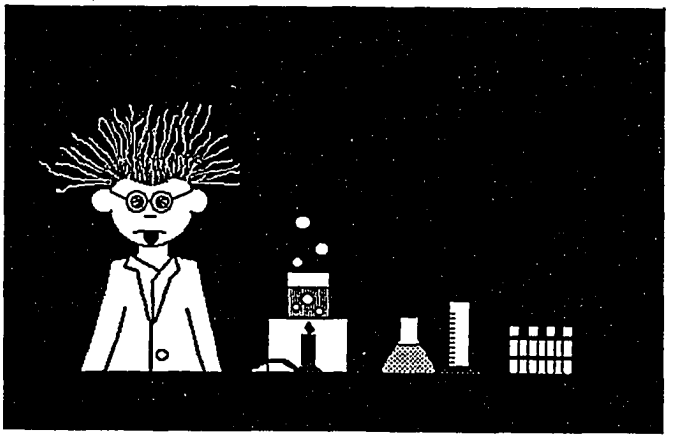
Click on the "Next" arrow when you are ready for the last set of practice problems.

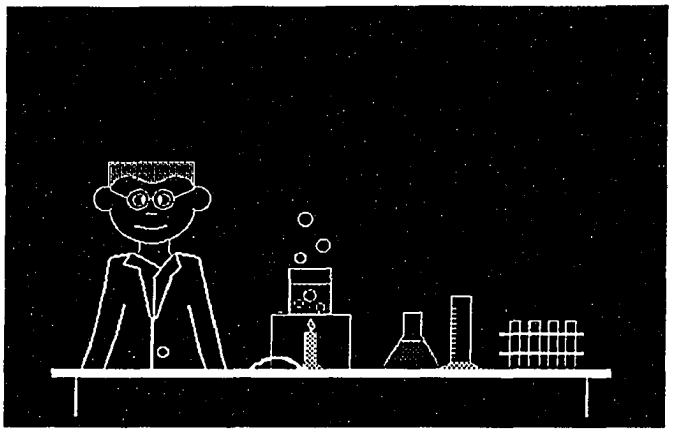
APPENDIX C

HARD COPY OF "DESIGNING CONTROLLED EXPERIMENTS" (CUED VERSION)









Designing Controlled Experiments

Welcome
[Student#1]
and
[Student#2]

Working together, you will both use this computer program to learn some important things about scientific experiments. [Student#2], start the program by using the mouse to point and click on the "next" arrow in the right corner below.

Getting Started

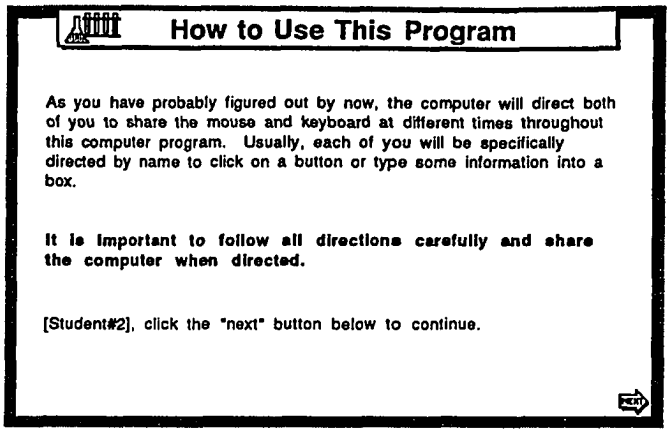
This computer program will present the following 3 lessons on scientific experimentation:

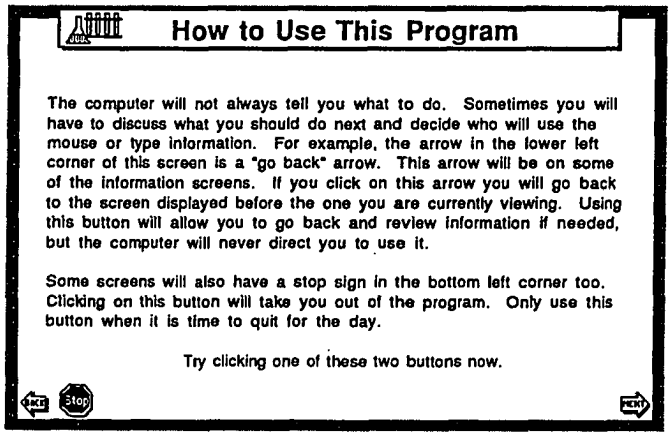
Lesson 1: The Steps in the Scientific Method

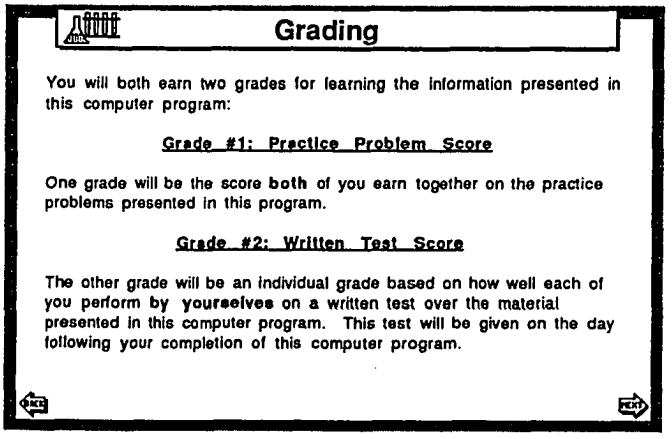
Lesson 2: The Parts of a Controlled Experiment

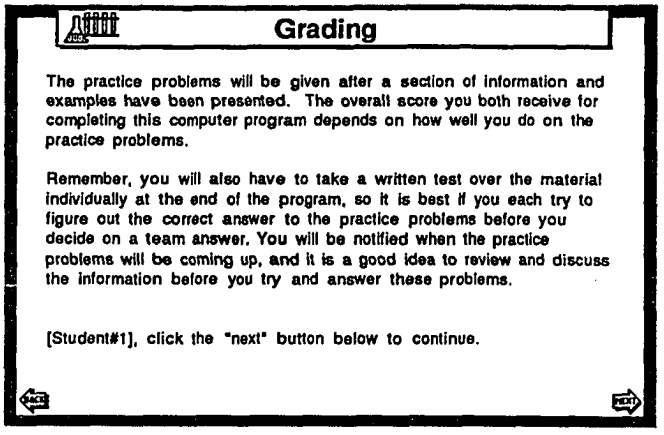
Lesson 3: How to Design a Controlled Experiment

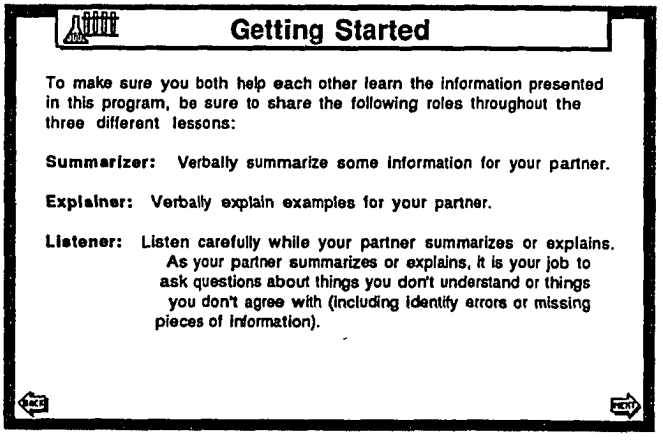
student1, click on the "next" button below to continue.

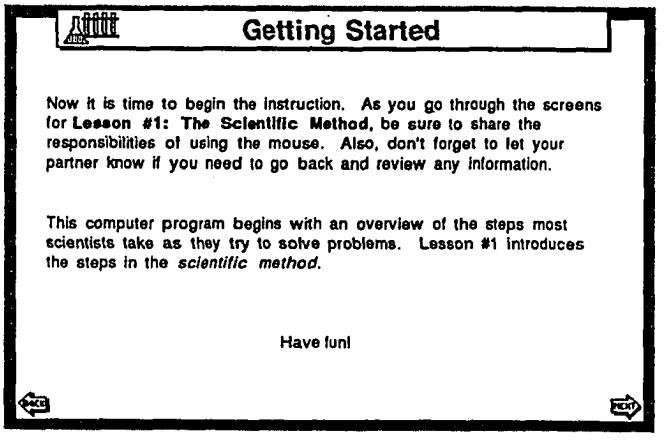








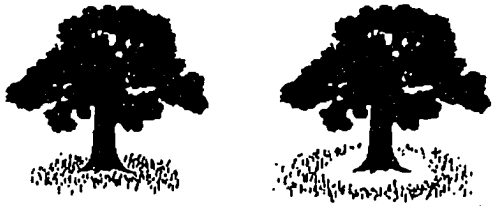




Lesson #1
The Scientific Method

Lesson #1 Introduction

Carefully examine the picture of the two trees below.



What differences do you notice between the two trees?

Lesson #1 Introduction

Did either of you notice that grass was growing directly under the tree on the left, but it was not growing within a circle directly under the tree on the right?

Why would grass be growing under one of the trees but not the other?

Suppose these were two identical trees growing in the same park. Could you make a guess as to why the grass would be growing underneath one of the trees but not the other?

Lesson #1 Introduction

Perhaps the tree without the grass growing directly under it is in a better location and more people sit under it for shade.

Perhaps the tree with the grass underneath it is closer to a trail where dogs are walked. The dogs tinkle under this tree and the grass grows more....or would the grass grow less?

Perhaps one tree gets more sun or water.

Perhaps one tree produces fruit, and the fruit falls off the tree and fertilizes the ground causing the grass to grow.

Perhaps the groundskeeper went out for doughnuts after trimming the grass around only one of the trees.

BACK NEXT

Lesson #1 Introduction

What could you do to find out exactly why the grass isn't growing the same around the two trees?

BACK NEXT

Lesson #1 Introduction

The steps you just went through demonstrate most of the steps in the SCIENTIFIC METHOD.

The scientific method is a specific procedure for identifying and trying to solve problems that arise from observations. Here are the steps in the order they are usually followed:

Step One: Making Observations
Step Two: Identifying a Problem
Step Three: Choosing a Hypothesis
Step Four: Making a Prediction
Step Five: Designing a Controlled Experiment
Step Six: Analyzing the Data/Conclusion

BACK NEXT

Lesson #1 Introduction

By examining the picture of the two trees, you are making **observations.**

By asking the question "Why is the grass growing differently underneath the two trees?" you are stating a **problem.**

By trying to guess why the grass was growing differently under the two trees, you are making a **hypothesis.**

Finally, you might do an **experiment** to determine if your hypothesis is right or wrong.

Lesson #1 Introduction

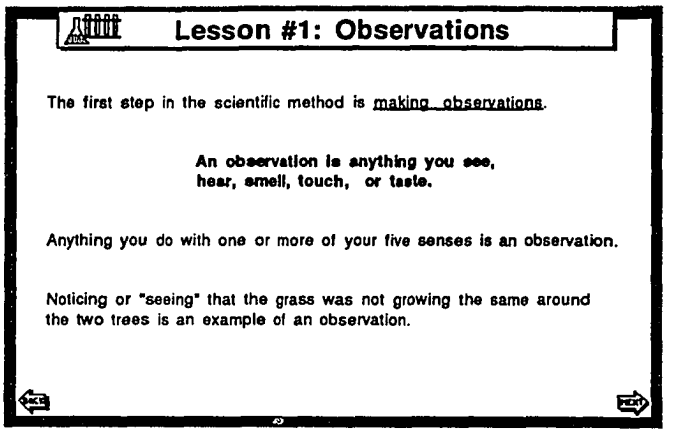
[Student#1] and [Student#2], after completing Lesson #1, you will have to demonstrate the following skills on a test:

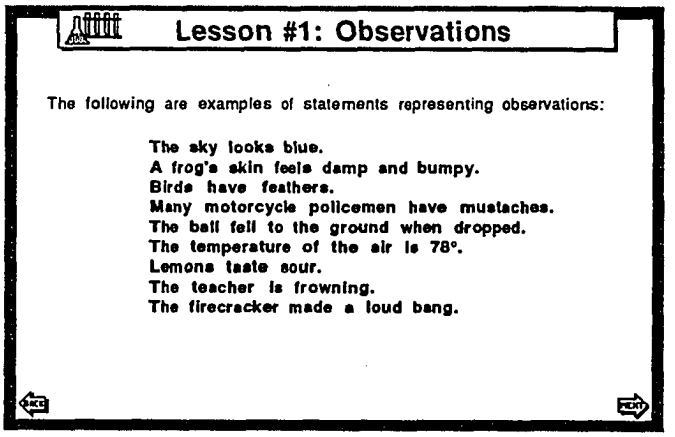
- Identify the definitions of the following terms:
  Observation, Problem, Hypothesis, Experiment
- Given a list of statements, identify each as either an **observation**, a **problem**, a **hypothesis**, a **prediction**, or a **conclusion** statement.

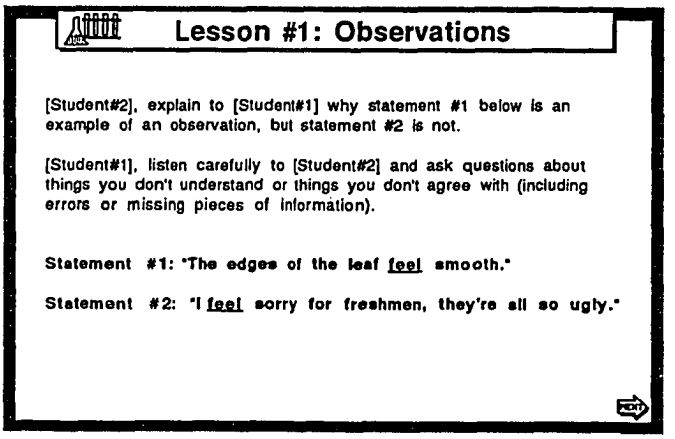
You will now be presented with the information necessary to teach you how to do both all the things listed above.

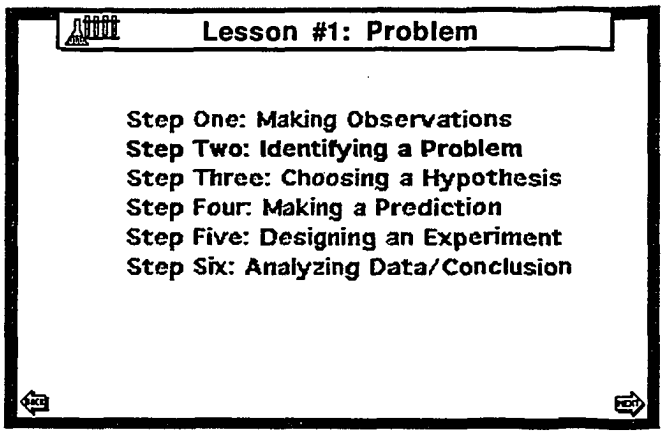
Lesson #1: Observations

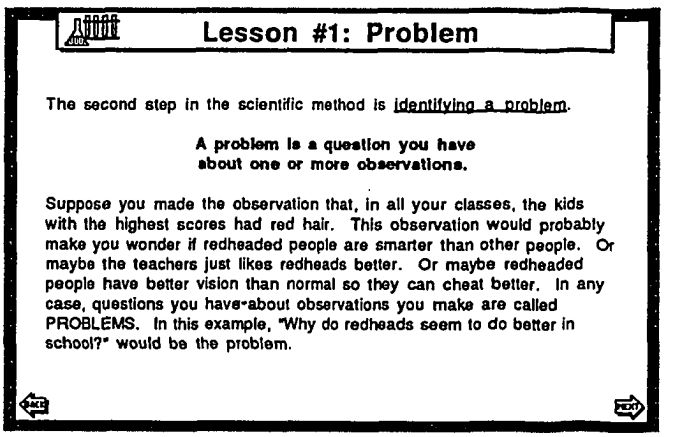
Step One: Making Observations
Step Two: Identifying a Problem
Step Three: Choosing a Hypothesis
Step Four: Making a Prediction
Step Five: Designing an Experiment
Step Six: Analyzing Data/Conclusion

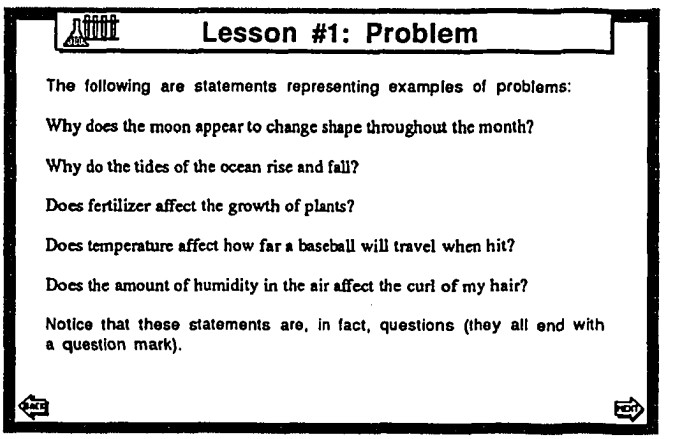


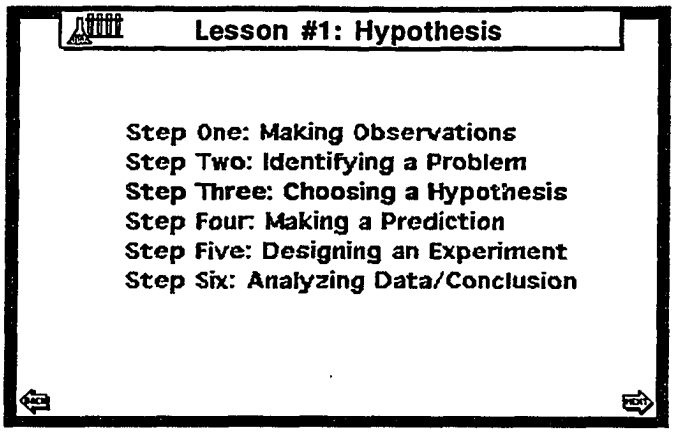


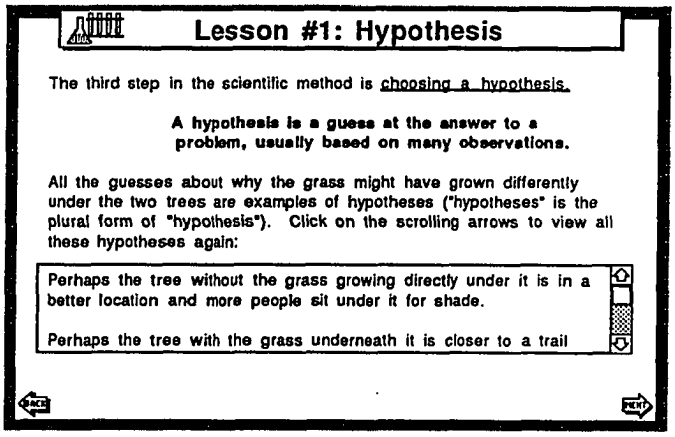


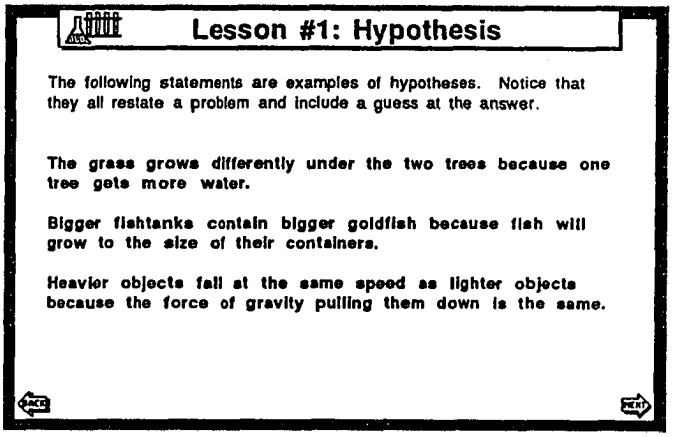


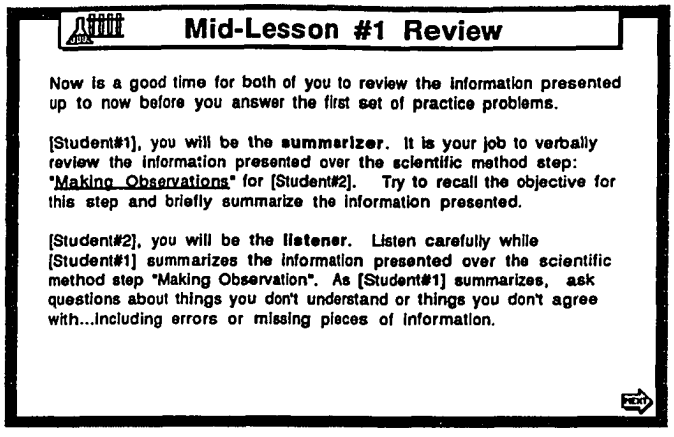


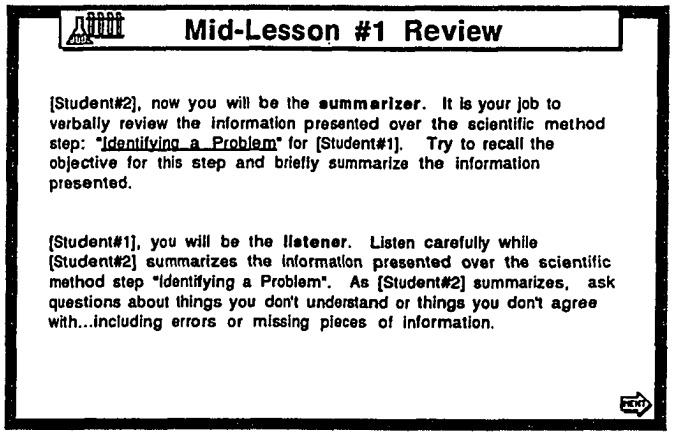


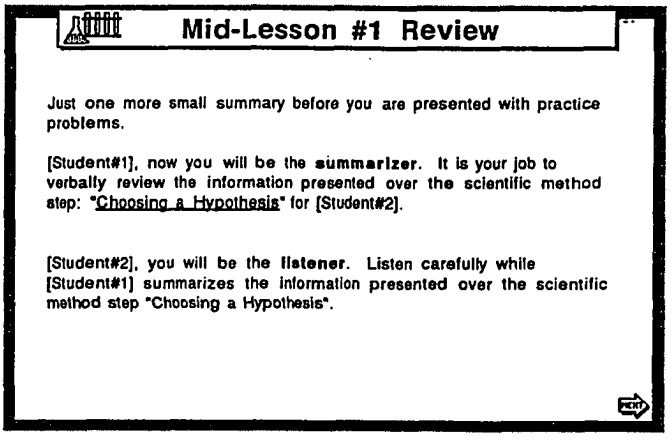












Lesson #1: Practice Item 1

Scientist Kevin wants to know if music affects the way a plant grows. He buys a houseplant and places it next to a radio. He plays the radio all day and all night for two months. Click on the statement below that describes an **observation** Kevin might make about plant growth.

a. The plant is healthy.

b. Why is the plant not growing?

c. The plant is not growing because it doesn't like the music.

d. The plant has grown 1/2 an inch in one month.

Lesson #1: Practice Item 2

Click on the statement below that best defines the word **problem** as it is used in the scientific method.

a. A question you have about one or more observations

b. A test on a hypothesis to see if it is true

c. A question you have about a hypothesis

d. Anything you do with one or more of your five senses

Lesson #1: Practice Item 3

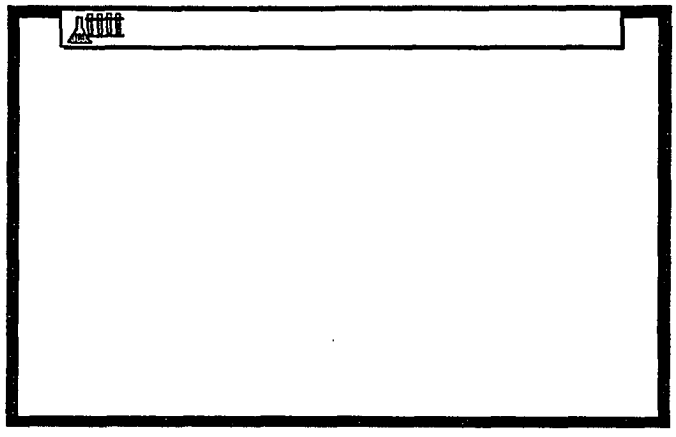
Scientist Kevin was having trouble getting a date for the prom. This was unusual because for the last three proms Kevin had to decide which dozen girls he would dump hard and which dozen he would let down easy before he picked the lucky one. Click on the statement below that best represents a **hypothesis** about Kevin's dating problem.

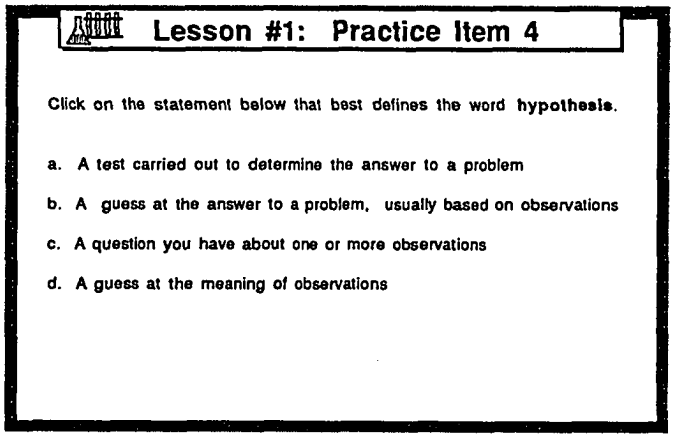
a. What is causing Kevin's dating problem?

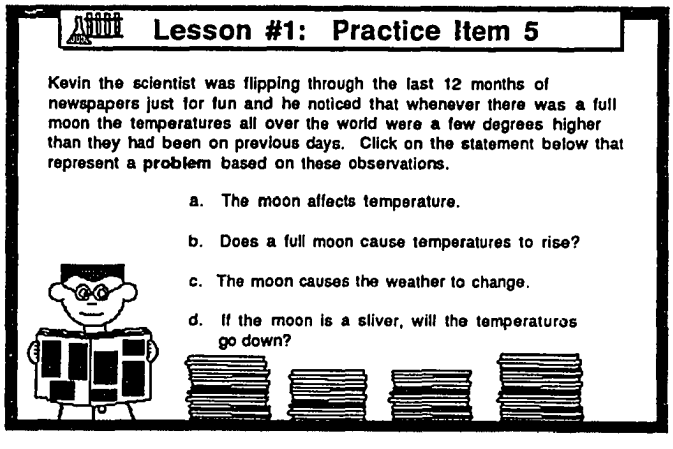
b. Kevin is having trouble getting a date.

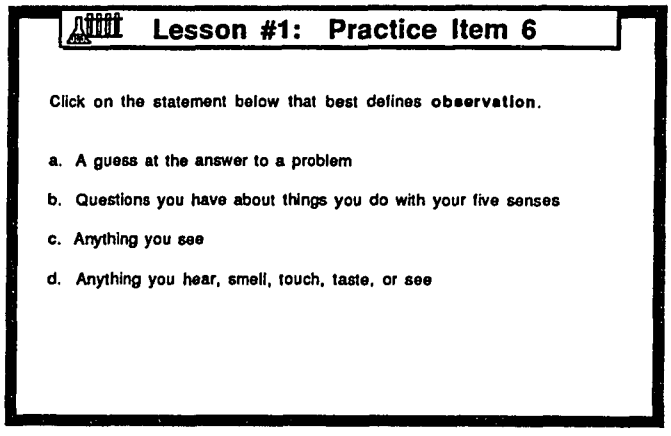
c. Kevin's dating problems are due to his new haircut.

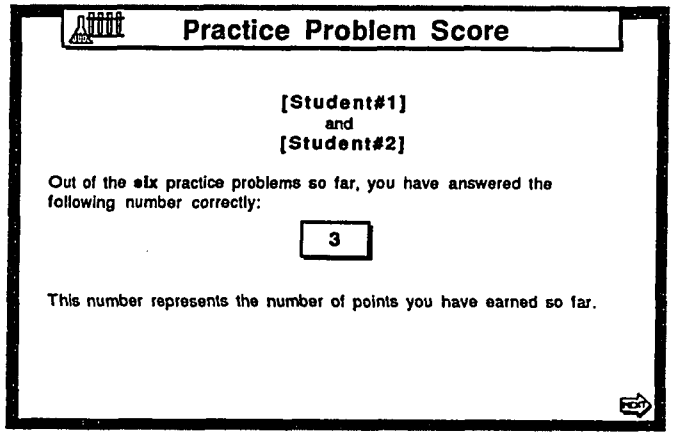
d. Many students are laughing at Kevin's new haircut.

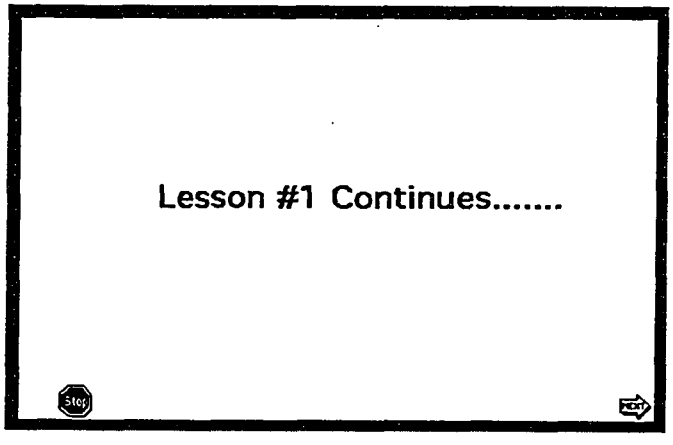












Lesson #1: Prediction

Step One: Making Observations
Step Two: Identifying a Problem
Step Three: Choosing a Hypothesis
Step Four: Making a Prediction
Step Five: Designing an Experiment
Step Six: Analyzing Data/Conclusion

NEXT

Lesson #1: Prediction

The next step in the scientific method is making a prediction. A prediction is a statement that contains the following three parts:

Part One: This part begins with the word **"If"** followed by a restatement of the hypothesis.

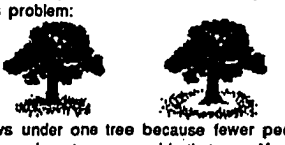
Part Two: This part begins with the word **"And"** followed by a brief description of a test on the hypothesis.

Part Three: This part begins with the word **"Then"** followed by a statement describing what should happen in the test if the hypothesis is, in fact, true.

BACK NEXT

Lesson #1: Prediction

Here is an example of a prediction statement using a hypothesis from the tree and grass problem:



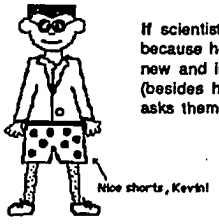
If more grass grows under one tree because fewer people sit under this tree, **and** a fence is put up around both trees, **then** the grass should grow the same under both trees.

Notice that all three parts of the prediction statement are included. The "If" is followed by a restatement of the hypothesis, the "and" describes a test, and the "then" describes what should happen in the test if the hypothesis is true.

BACK NEXT

Lesson #1: Prediction

Here is another example of a prediction statement:



If scientist Kevin can't get a date to the prom because he has a bad haircut, and he gets a new and improved haircut, then somebody (besides his mother) will say "yes" when he asks them to the dance.

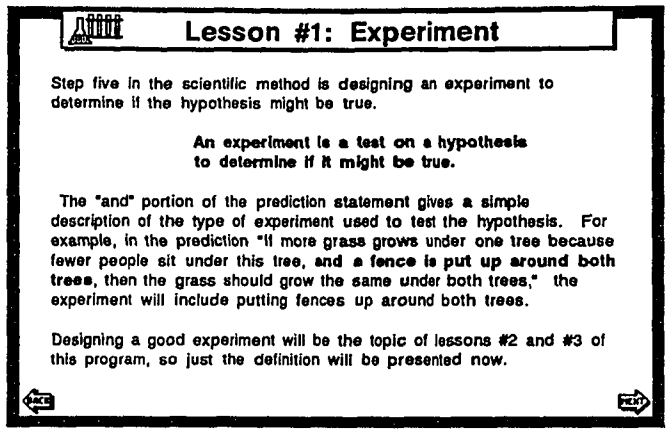
Lesson #1: Prediction

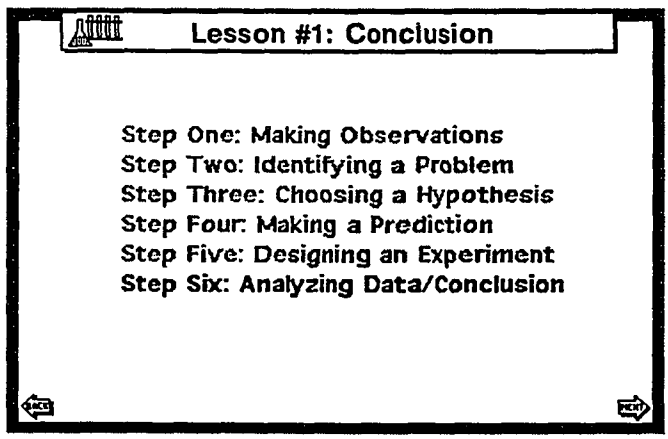
[Student#1], explain why the statement below is **not** a good example of a prediction statement. [Student#2], listen carefully to [Student#1] and remember to ask questions about things you don't understand or things you don't agree with.

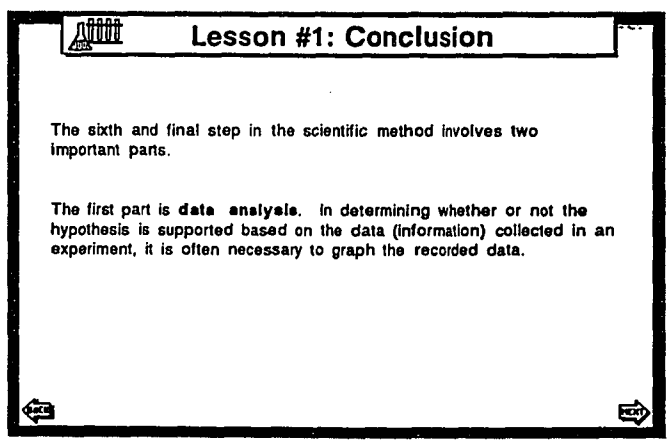
"I predict that the earth is round because if I fly an airplane in a straight line long enough I will end up where I started."

Lesson #1: Experiment

Step One: Making Observations
Step Two: Identifying a Problem
Step Three: Choosing a Hypothesis
Step Four: Making a Prediction
Step Five: Designing an Experiment
Step Six: Analyzing Data/Conclusion







Lesson #1: Conclusion

Imagine you performed an experiment to test the hypothesis that music makes plants grow better. You performed an experiment which included a plant grown in a room with music and a plant grown in a room without music. You recorded the following information over ten days:

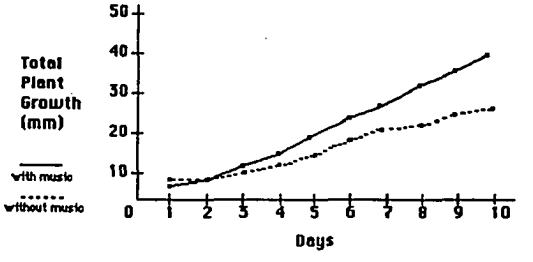
Growth of plant with music		Growth of plant without music	
Day 1- 5mm	Day 6- 4mm	Day 1- 7mm	Day 6- 3mm
Day 2- 4mm	Day 7- 3mm	Day 2- 2mm	Day 7- 2mm
Day 3- 3mm	Day 8- 5mm	Day 3- 5mm	Day 8- 1mm
Day 4- 3mm	Day 9- 4mm	Day 4- 2mm	Day 9- 5mm
Day 5- 4mm	Day 10- 4mm	Day 5- 2mm	Day 10- 1mm

Based on this data, could you say your hypothesis is true? A graph might help. Click the "next" arrow to see a graph of total plant growth based on this data.

BACK NEXT

Lesson #1: Conclusion

Here is a graph of the data from the previous screen. Notice that the plant grown in the room with the music appears to have grown more.



BACK NEXT

Lesson #1: Conclusion

The second part of step six in the scientific method is making a **conclusion.**

A conclusion is simply a statement that says:

"Based on the data, my hypothesis is supported/not supported."

A hypothesis is supported if the "then" part of the prediction statement turns out to be true once the experiment has been completed.

BACK NEXT

Lesson #1: Conclusion

To illustrate how a conclusion statement is determined, an example of a simple experiment is needed.

In the tree and grass example, a hypothesis for the problem "Why is the grass growing differently under the two trees?" could be that people are sitting under one tree more than the other. The tree with no grass under it has more people sitting beneath it. A prediction statement for this problem and hypothesis would read:

If more grass grows under one tree because fewer people sit under this tree, **and** a fence is put up around both trees, **then** the grass should grow the same under both trees."

BACK NEXT

Lesson #1: Conclusion

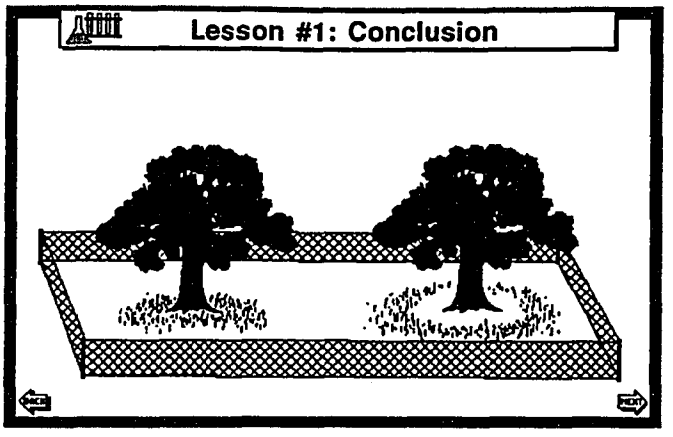
Remember, the hypothesis states that the grass is not growing under the tree on the right because more people sit under this tree.

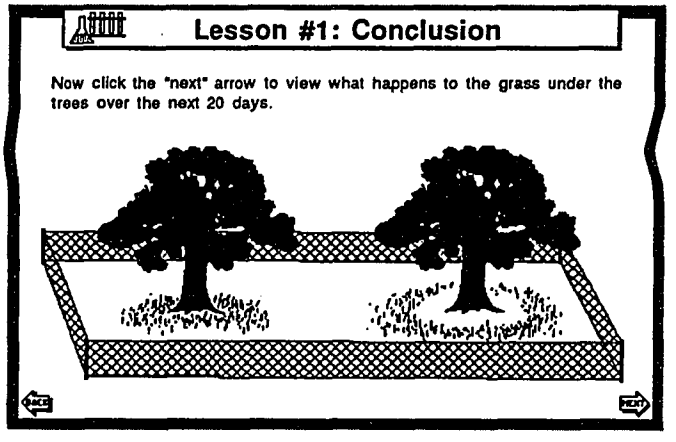
Click the "next" arrow to carry out a simple experiment by building a fence around the trees.

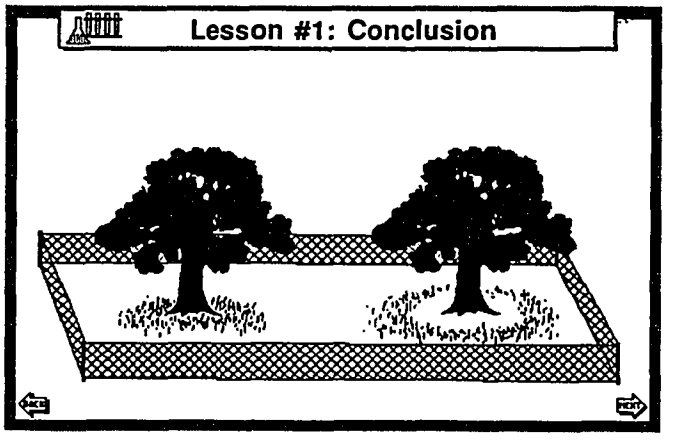
BACK NEXT

Lesson #1: Conclusion

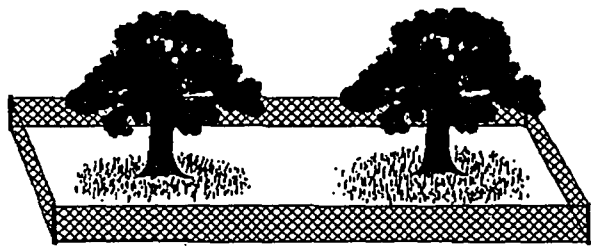
BACK NEXT





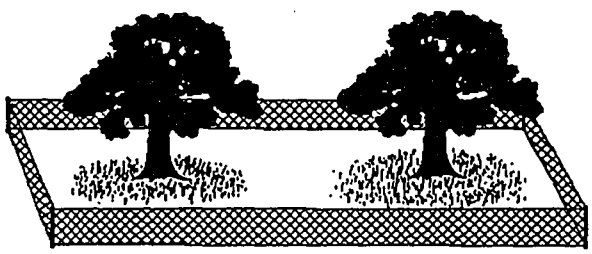


Lesson #1: Conclusion



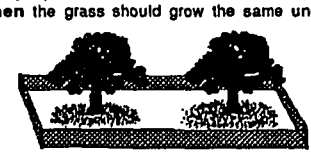
Lesson #1: Conclusion

Observe the grass growing under both trees! Click the "next" arrow to see how this data matches the prediction.



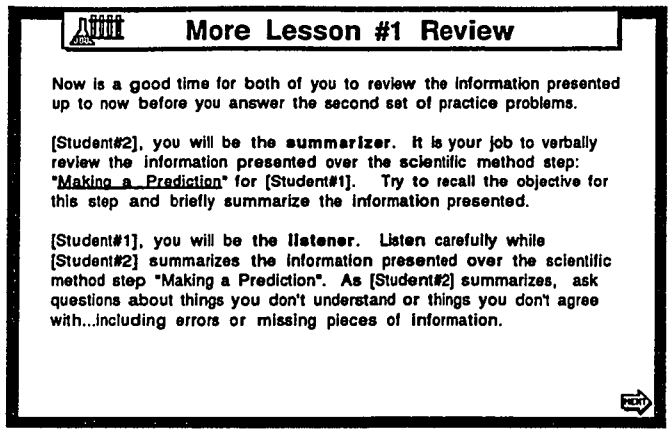
Lesson #1: Conclusion

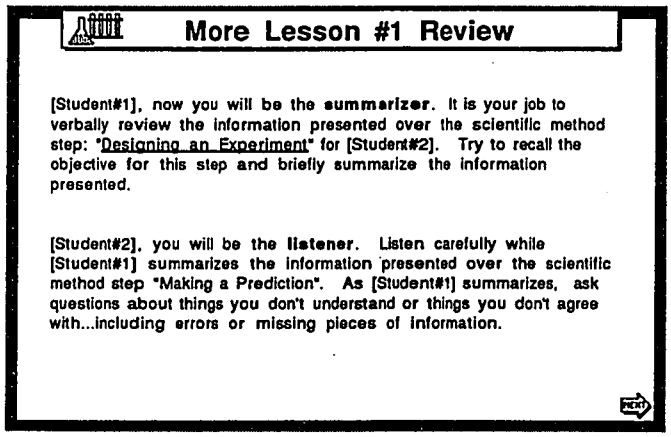
Recall the prediction statement: If more grass grows under one tree because fewer people sit under this tree, **and** a fence is put up around both trees, **then** the grass should grow the same under both trees.

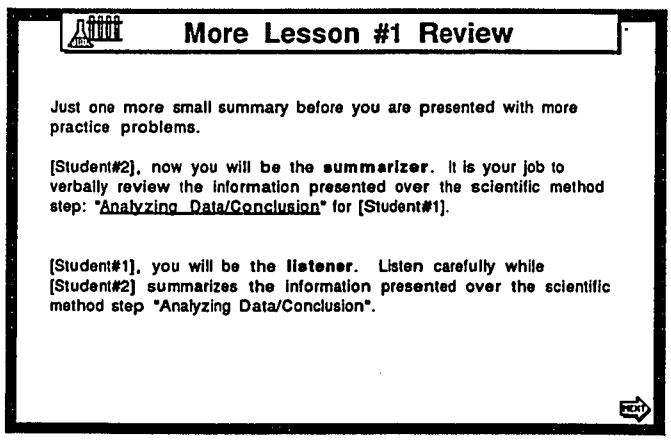


Since the grass **did** grow the same under both trees, the conclusion statement would say:

"Based on the data, my hypothesis is supported."







Lesson #1: Practice Item 7

Click on the definition below that best defines the term **experiment**.

a. Testing a problem to determine the answer

b. A guess at the answer to a problem

c. An investigation to determine which observations lead to problems

d. A test on a hypothesis to determine if it might be true

Lesson #1: Practice Item 8

A farmer had a hypothesis that adding sugar to the water he gave his tomato plants would help them grow bigger. He carried out an experiment, and after 30 days the plants given the sugar water averaged twelve inches taller than the plants given plain water. Click on the statement below that could be a conlcusion statement for this experiment.

a. "The data indicate that sugar helped the tomato plants grow taller."

b. "Based on the data, sugar helps tomato plants grow bigger."

c. "Based on the data, my hypothesis is supported."

d. "The data prove that sugar makes plants grow bigger."

Lesson #1: Practice Item 9

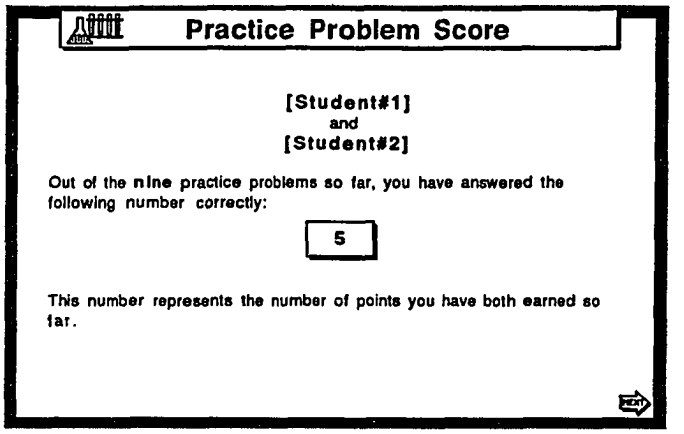
Click on the statement below that is an example of a prediction statement.

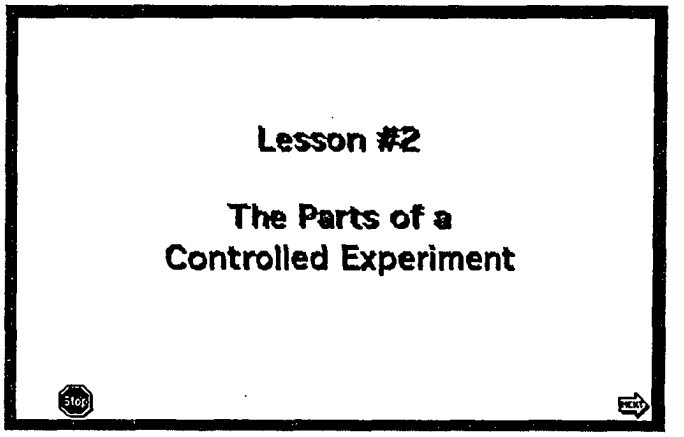
a. If sugar is put in a plant's water, and plain water is given to another plant, then the plant given the sugar in the water will grow bigger.

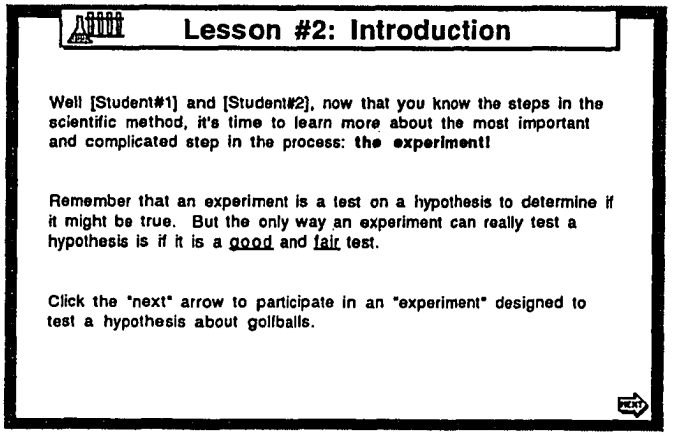
b. If sugar makes plants grow bigger, and some plants are given sugar water while other plants are given plain water, then the plants given sugar water will grow bigger.

c. Plants are living organisms, and they need energy to grow, so sugar should help them grow bigger.

d. Putting sugar in a plant's water should help it grow bigger.







Lesson #2: Introduction

Suppose you are a golfer, and you observe that on hot days your ball seems to travel much farther when you hit it.

You come up with the following three hypotheses:

1. The hotter air creates less friction for the ball to travel through.
2. Your muscles work better when it is hot.
3. The hotter temperatures cause the rubber in the ball to be hotter, making the ball more "springy" and causing it to travel farther.

You decide to perform an experiment to see if hypothesis #3 is correct.

Click the "next" arrow to see the prediction statement.

BACK NEXT

Lesson #2: Introduction

If golfballs travel farther on hotter days because the rubber in the ball is hotter, making the ball more "springy" and causing it to travel farther, **and** one ball is heated while another is cooled before both are hit with a golf club, **then** the hotter ball will travel farther.

To test your hypothesis, you dig around in your uncle's golf bag and find two balls. You microwave one ball until it starts to smoke, and drop the other ball into your friend's 48-ounce "SuperCola Freezee". You and your friend each grab a golf club and you tee off in the neighbor's yard.

Click the "next" arrow to view the results.

BACK NEXT

Lesson #2: Introduction

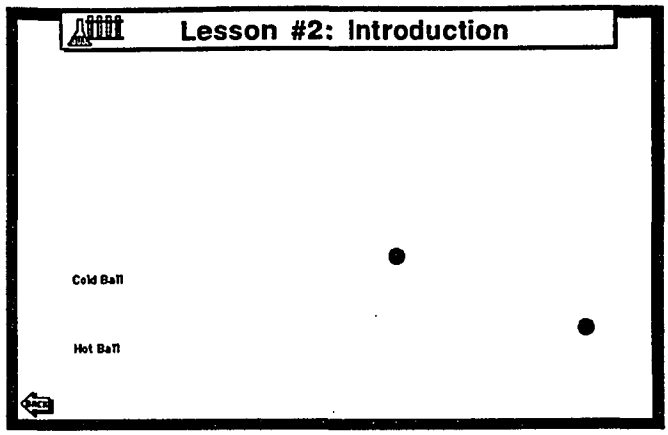
[Student#2], you pulled out an 5-iron and hit the cold ball. Click on the cold ball below to see how far it flew.

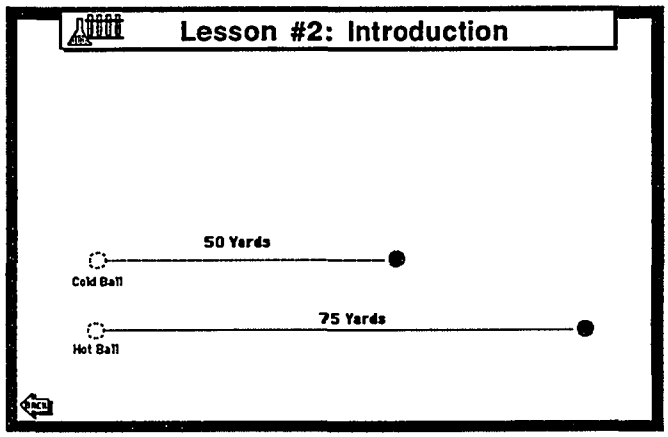
[Student#1], you chose another golf club and hit the hot ball. You click on this ball to see how far it flew.

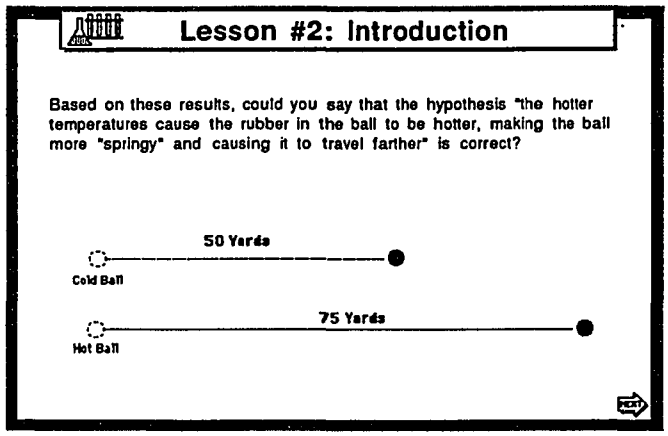
Cold Ball

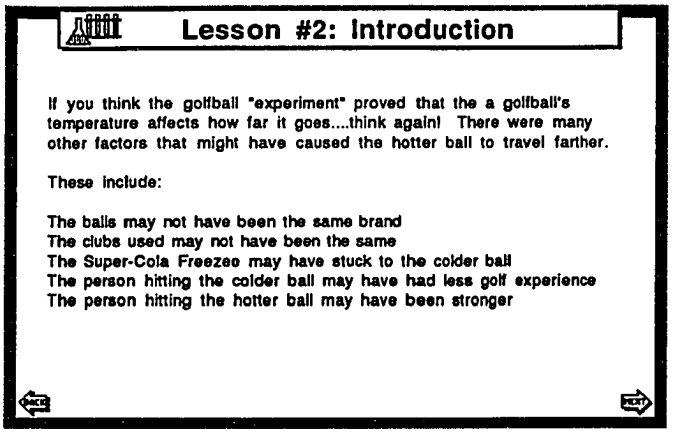
Hot Ball

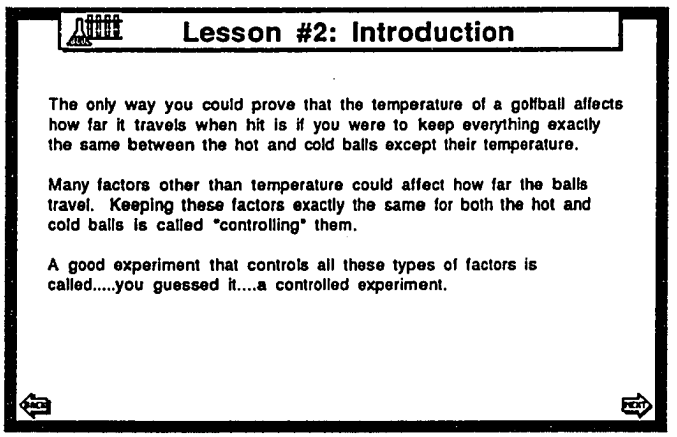
BACK

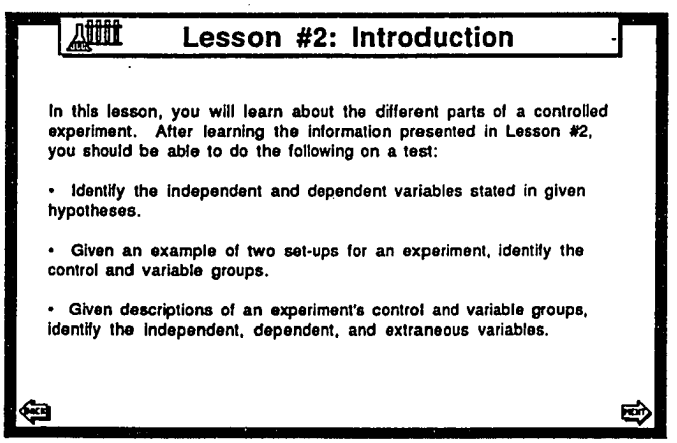


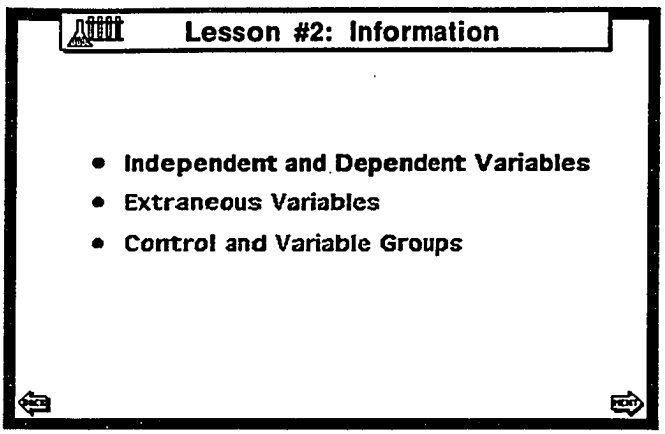


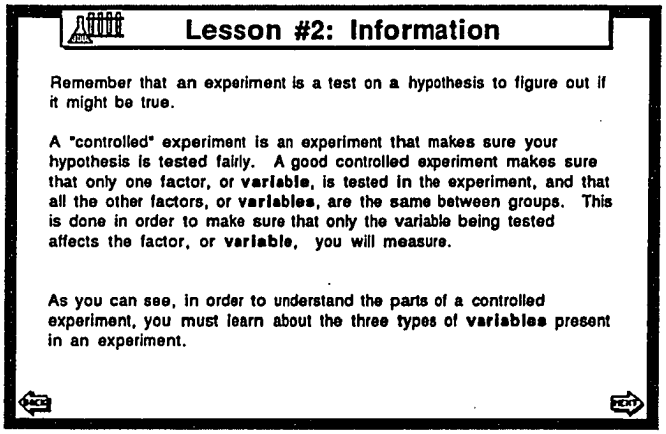


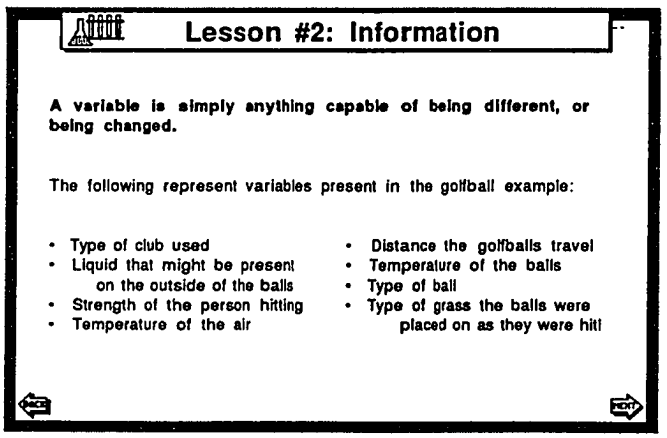












Lesson #2: Information

What were some of the variables present in the "grass under the tree" experiment?

Lesson #2: Information

There are usually two different kinds of variables stated in a hypothesis.

The following hypotheses have the two variables underlined:

1. Music has an effect on plant growth.
2. The temperature of a golfball affects how far it travels when hit.
3. The amount of grass growing under the trees is different because they get different amounts of sunlight.

The two types of variables in each hypothesis are called the **independent** and the **dependent** variables.

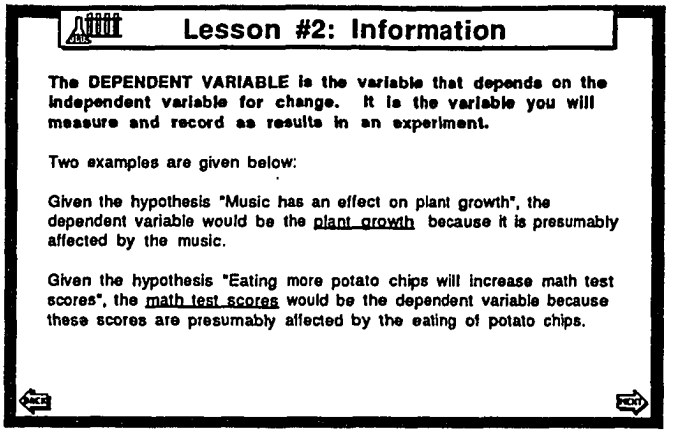
Lesson #2: Information

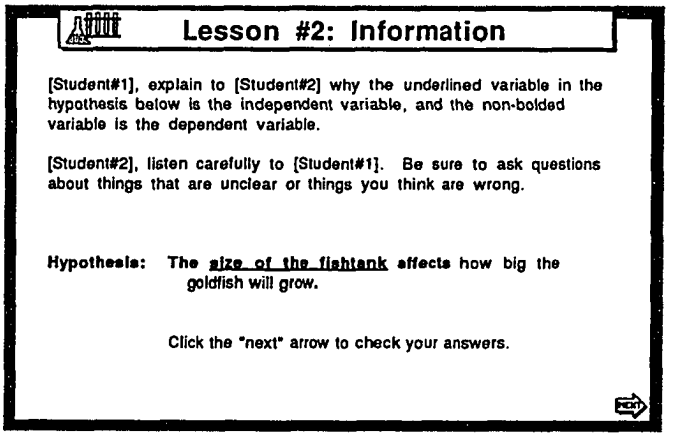
The INDEPENDENT VARIABLE is the presumed cause of change or effect stated in the hypothesis. It is the experimental variable that you would introduce and test in an experiment.

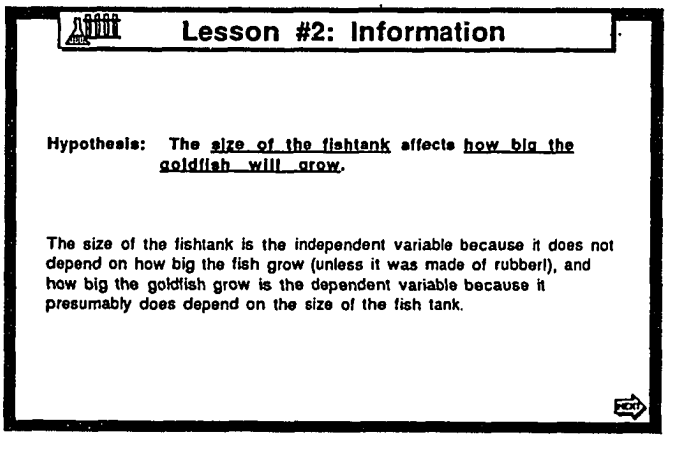
Two examples are given below:

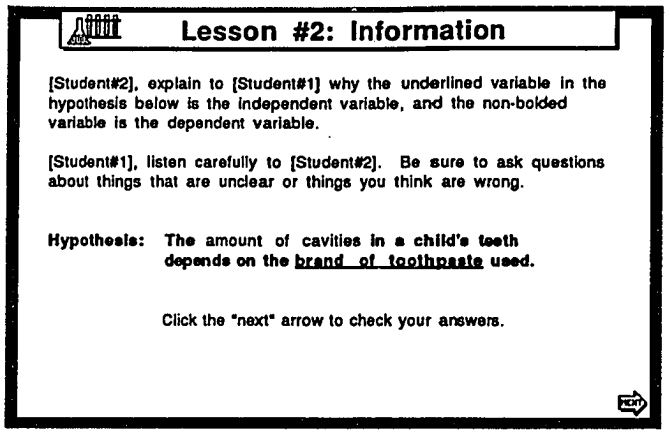
Given the hypothesis "Music has an effect on plant growth", the independent variable would be the music (it presumably affects plant growth).

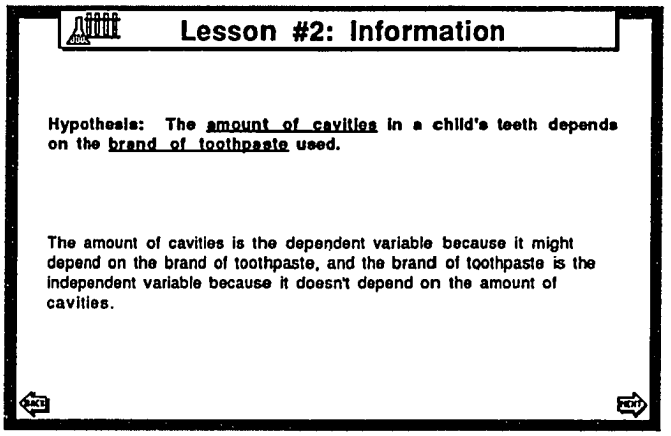
Given the hypothesis "Eating more potato chips will increase math test scores", the amount of potato chips would be the independent variable (it presumably affects math test scores).

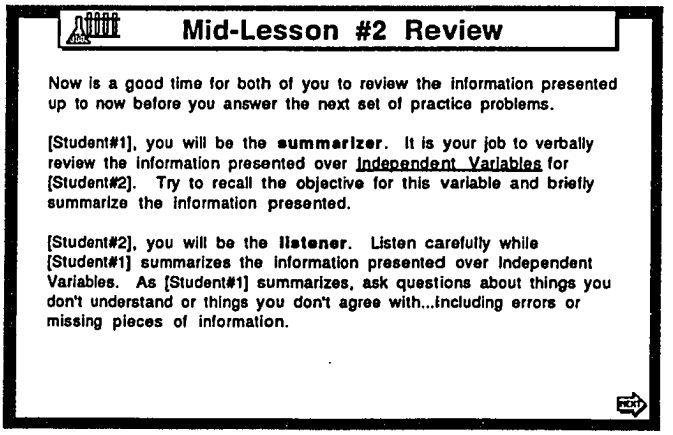


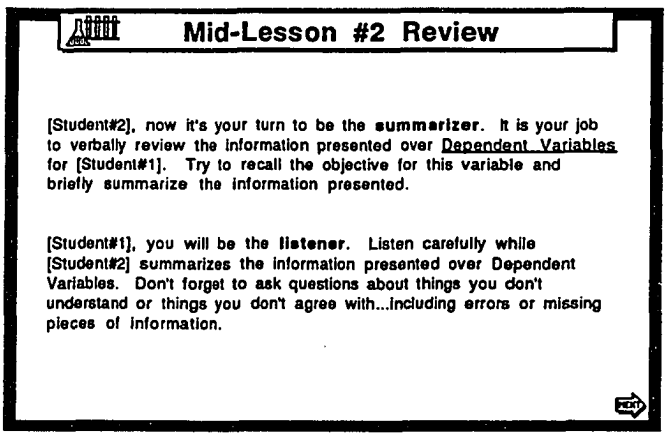


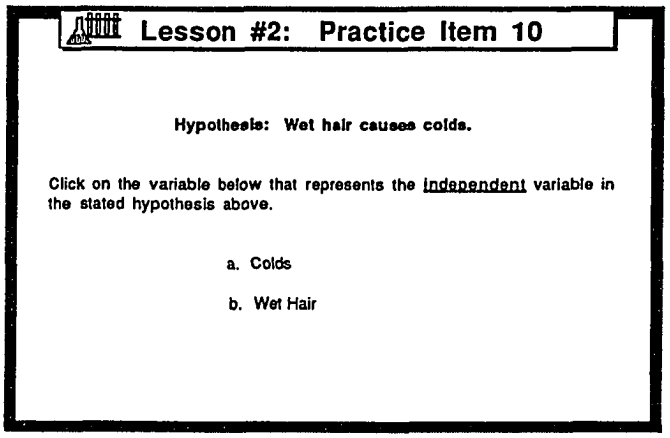


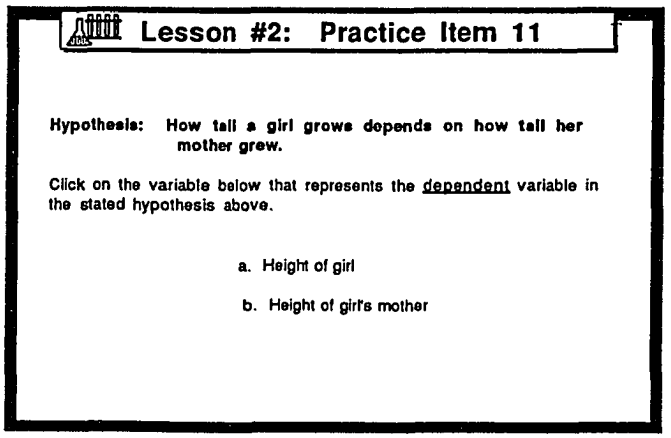


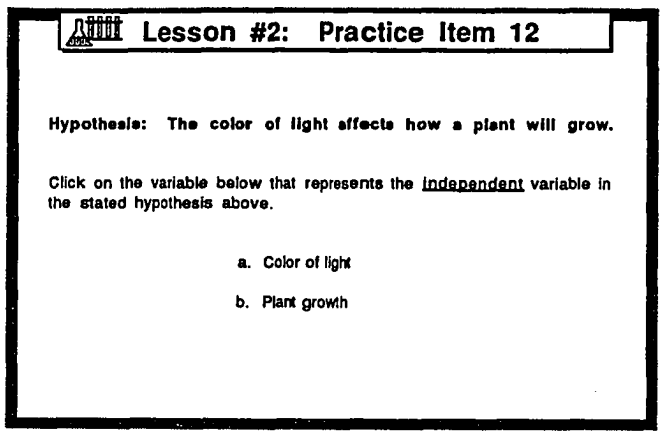


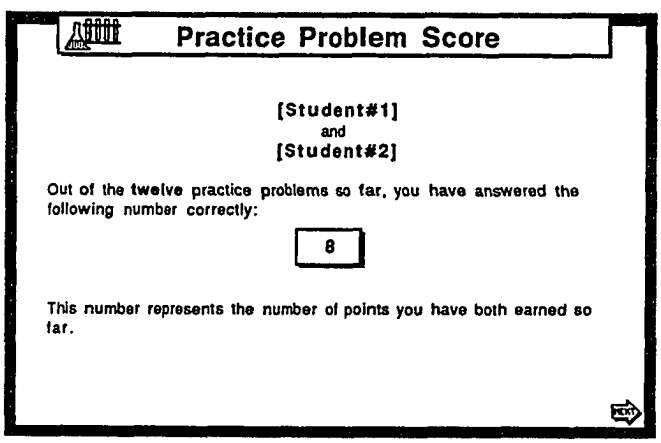


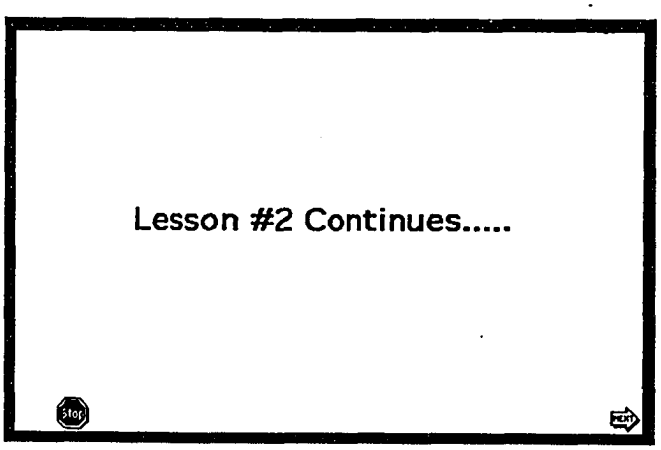


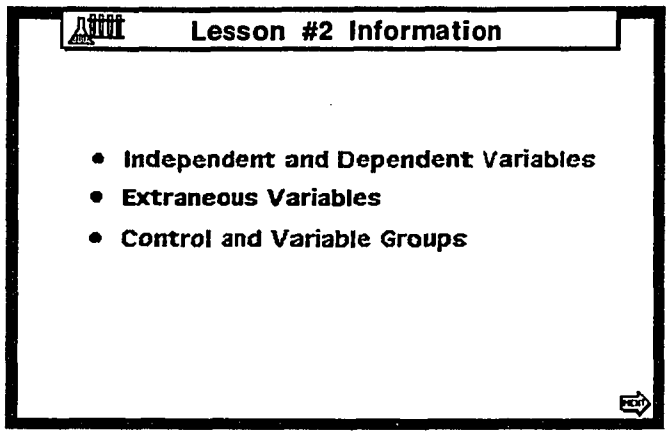


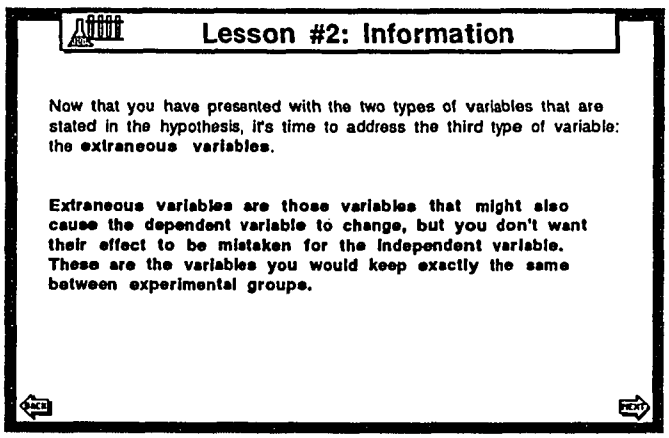


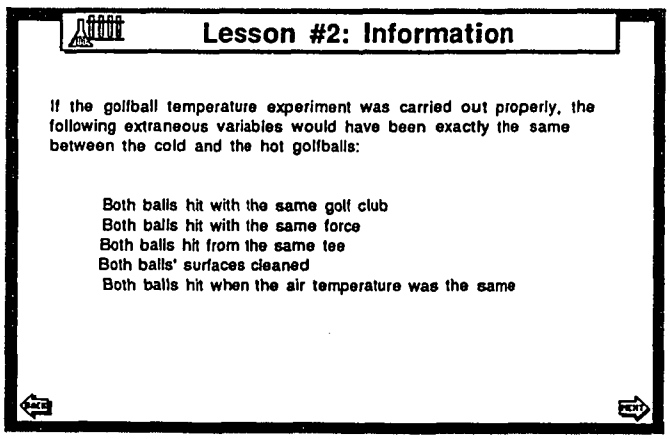












Lesson #2: Information

- Independent and Dependent Variables
- Extraneous Variables
- Control and Variable Groups

Lesson #2: Information

Most controlled experiments contain at least two groups or "set-ups". There is usually one "control" group and one or more "variable" groups.

A **control group** is a set-up in an experimental design that contains all the variables but not the independent variable.

A **variable group** is set-up in an experimental design that contains the exact same extraneous variables as in the control group but it also includes the independent variable.

Lesson #2: Information

A good example of a controlled experiment containing one variable group and a control group is the following plant experiment.

Suppose that every time you tried to grow plants in your room at home, they shriveled up and died within a week. This bothered you because plants were usually your only real friends. Now suppose you had an uncle who grew the biggest, healthiest-looking houseplants you had ever seen. You decided to visit him and figure out what he does differently. After spending a few afternoons watching him work his plant magic, you were stumped. He seemed to do everything the same way you did. The only difference being a liquid plant food he gave his plants weekly.

Lesson #2: Information

Based on this information, you arrive at the following hypothesis about the problem "Why do my uncle's plants grow better than mine?":

Hypothesis: Plant food increases the growth of plants.

You create the following prediction statement using this hypothesis.

If plant food increases the growth of plants, **and** I grow one plant with plant food and one without, **then** the plant given the plant food will grow more.

Using the "and" part of the prediction statement above, you design an experiment to test your hypothesis.

BACK NEXT

Lesson #2: Information

This illustration shows the two set-ups in your experiment:

BACK NEXT

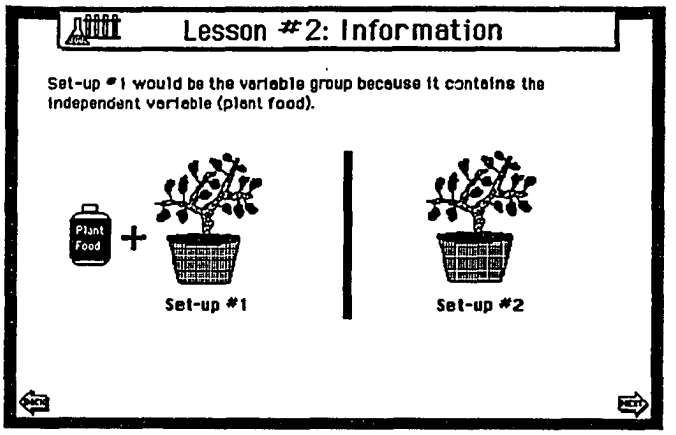
Lesson #2: Information

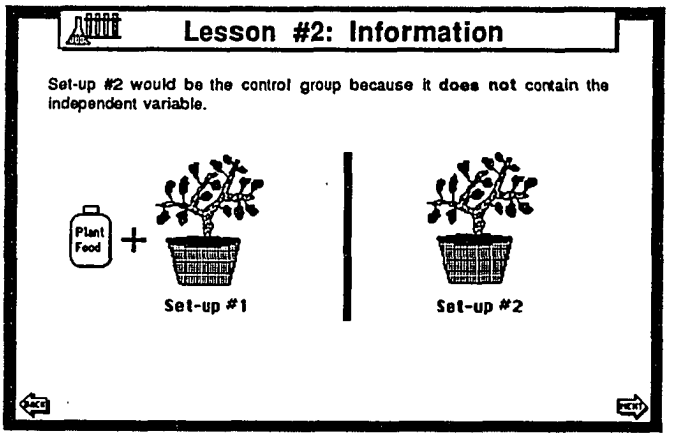
The following list represents most of the variables included in your plant experiment:

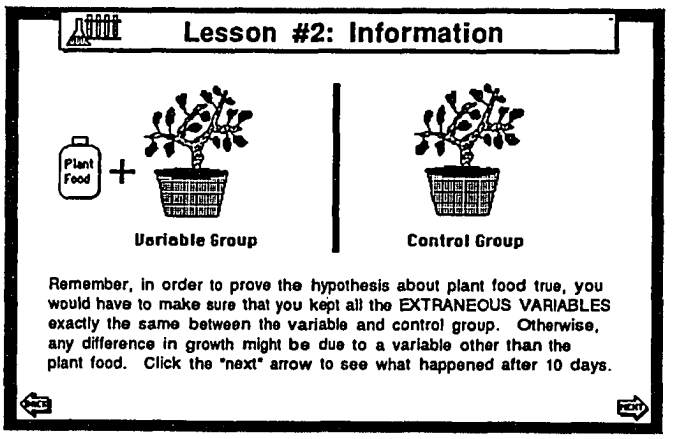
- -amount of plant food
- -amount of water given to each plant
- -temperature of air
- -amount of growth each day
- -type of plants
- -type of potting soil
- -amount of light received by each plant
- -amount of potting soil

Given the hypothesis "Plant food increases plant growth", which of the variables above would be the independent variable? Click on this variable now.

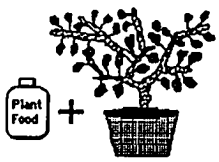
BACK







Lesson #2: Information



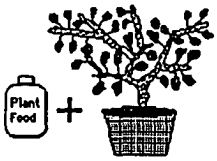
Variable Group

Control Group

Remember, in order to prove the hypothesis about plant food true, you would have to make sure that you kept all the EXTRANEOUS VARIABLES exactly the same between the variable and control group. Otherwise, any difference in growth might be due to a variable other than the plant food. Click the "next" arrow to see what happened after 10 days.

BACK NEXT

Lesson #2: Information



Variable Group

Control Group

The only way this data could prove the hypothesis true is if the following extraneous variables are exactly the same for the variable and control groups: type and amount of soil, type of pot, type of plant, amount of light, temperature.

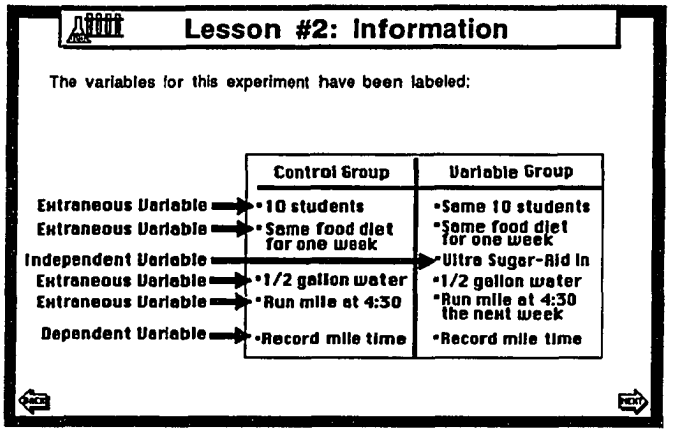
BACK NEXT

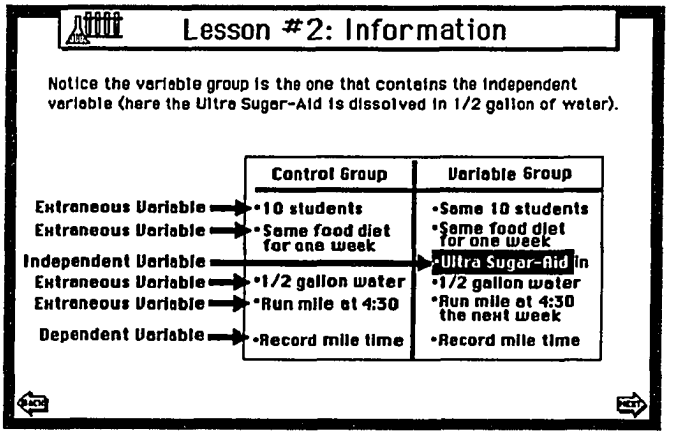
Lesson #2: Information

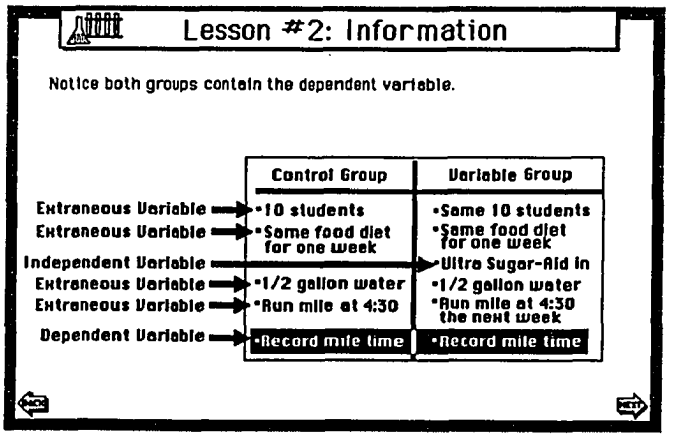
Here is another example of an experiment with one variable and one control group. Scientist Kevin wanted to find out if drinking Ultra Sugar-Aid would help the students in his P.E. class run better. He always felt stronger after drinking a tall, cool glass of tropical punch flavor, so his hypothesis was that drinking Ultra Sugar-Aid would make students run the mile faster. To test this hypothesis he set up the following experimental groups:

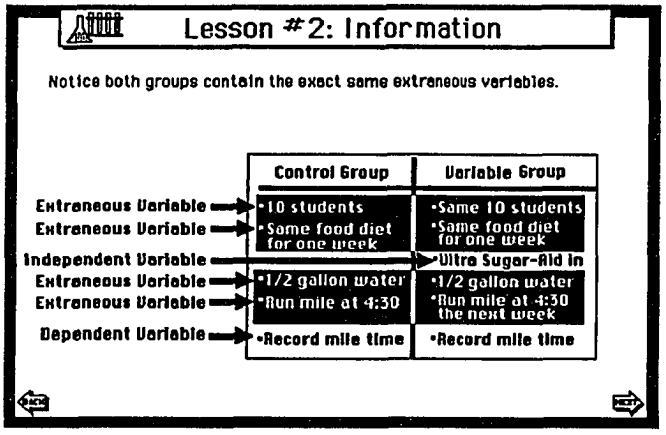
Control Group	Variable Group
•10 students	•Same 10 students
•Same food diet for one week	•Same food diet for one week
•1/2 gallon water	•1/2 gallon Ultra Sugar-Aid
•Run mile at 4:30	•Run mile at 4:30 the next week
•Record mile time	•Record mile time

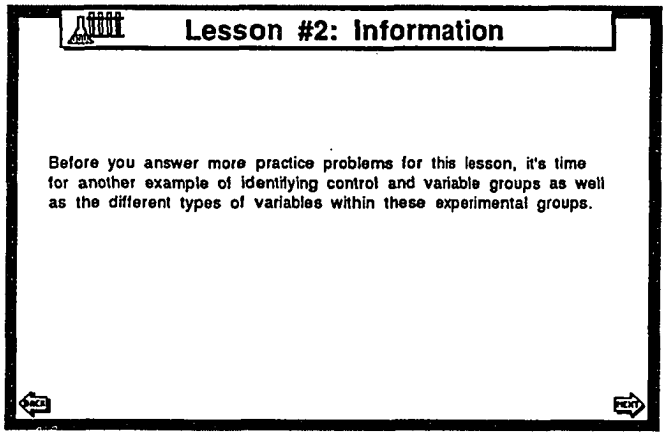
BACK NEXT

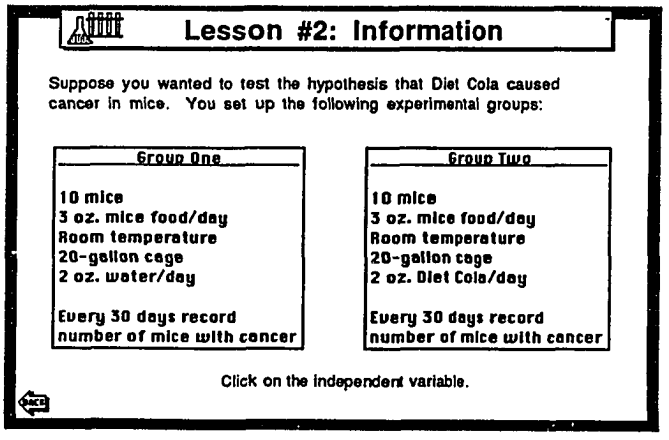


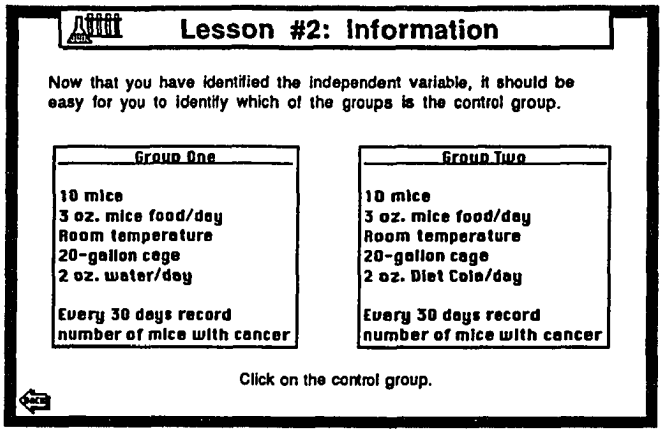


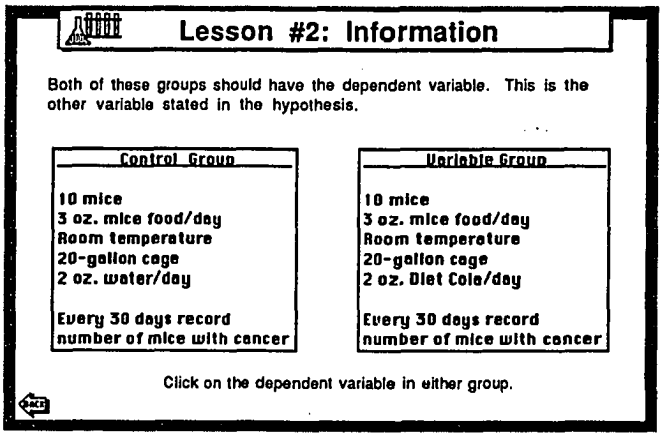


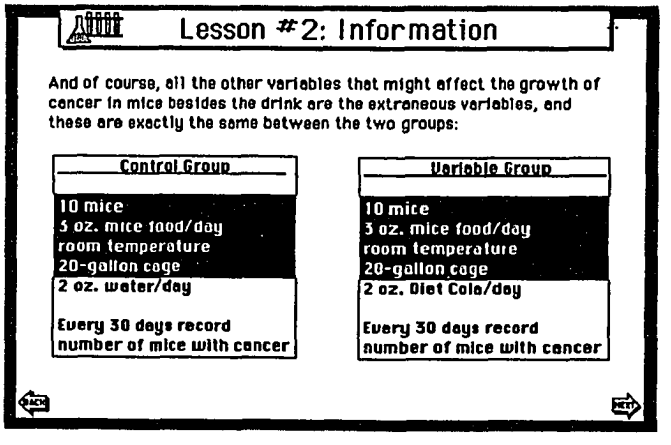


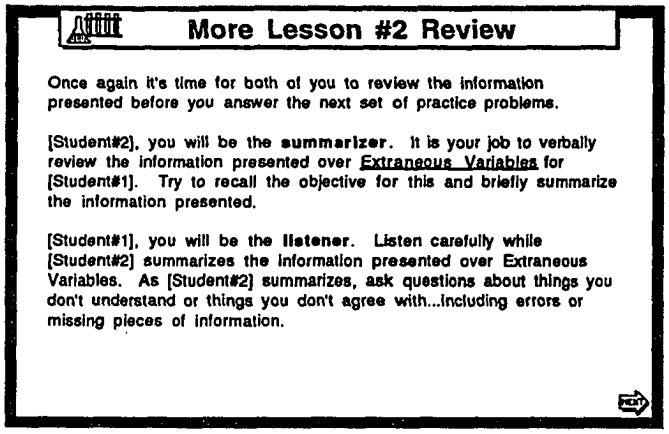


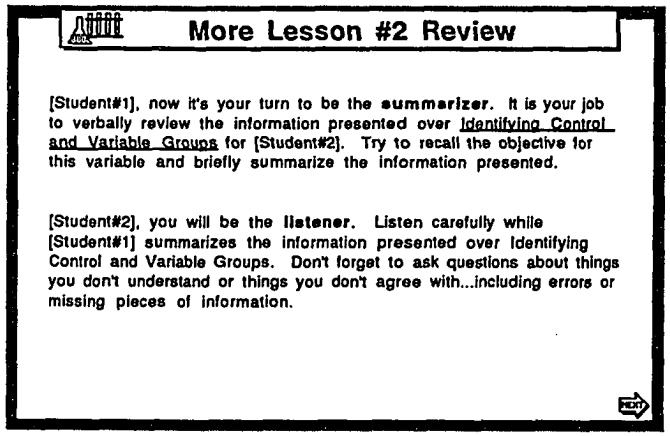


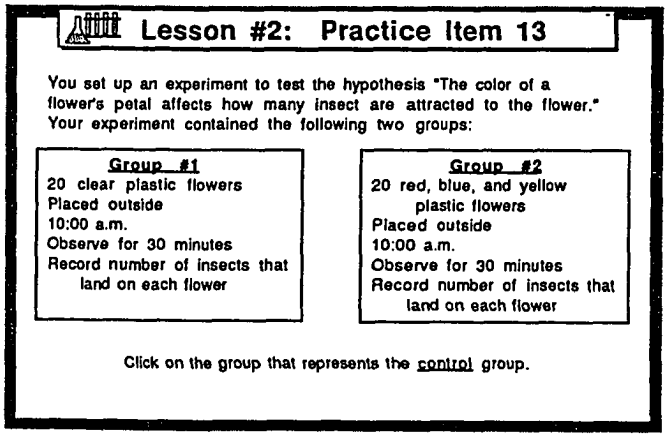












Lesson #2: Practice Item 14

Click on the variable listed below that would be the dependent variable in an experimental set-up designed to test the hypothesis "The color of a flower's petals affect how many insects are attracted to it.".

a. 20 red, blue, and yellow plastic flowers

b. Placed outside at 10:00 a.m.

c. Observe for 30 minutes

d. Number of insects that land on each flower

e. All of the above

Lesson #2: Practice Item 15

Click on the variable listed below that would be the independent variable in an experimental set-up designed to test the hypothesis "The color of a flower's petals affect how many insects are attracted to it".

a. 20 red, blue, and yellow plastic flowers

b. Placed outside at 10:00 a.m.

c. Observe for 30 minutes

d. Number of insects that land on each flower

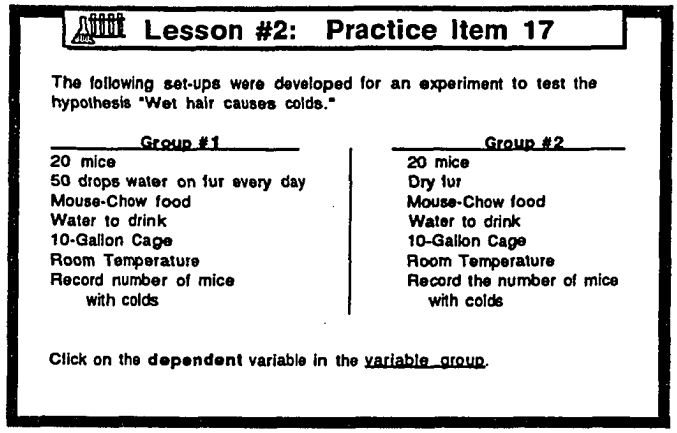
e. None of the above

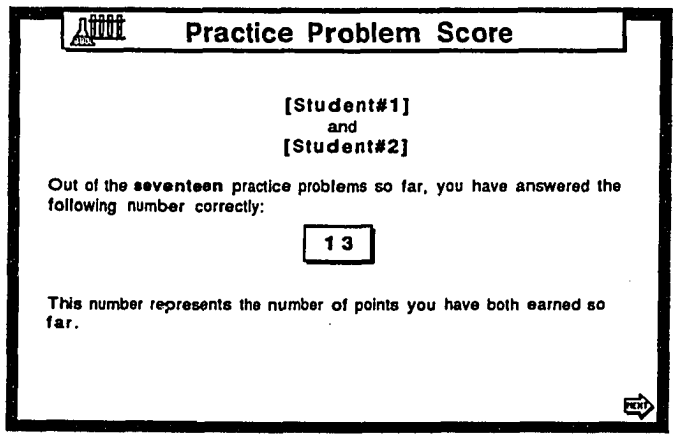
Lesson #2: Practice Item 16

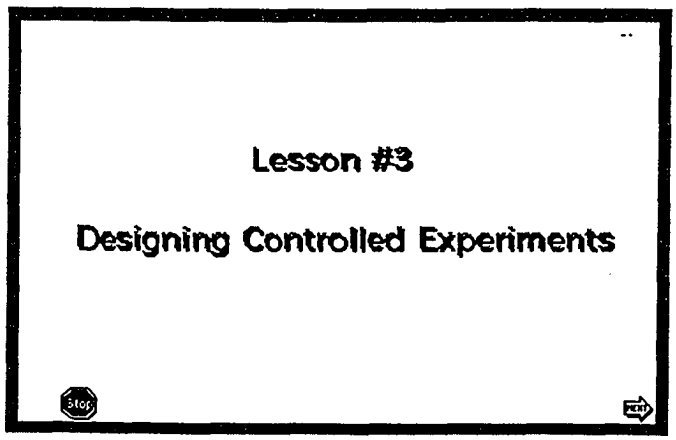
The following set-ups were developed for an experiment to test the hypothesis "Wet hair causes colds."

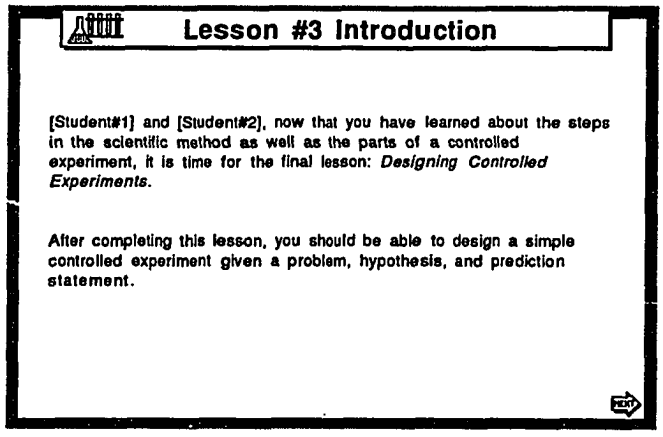
Group #1	Group #2
20 mice	20 mice
50 drops water on fur every day	Dry fur
Mouse-Chow food	Mouse-Chow food
Water to drink	Water to drink
10-Gallon Cage	10-Gallon Cage
Room Temperature	Room Temperature
Record number of mice with colds	Record the number of mice with colds

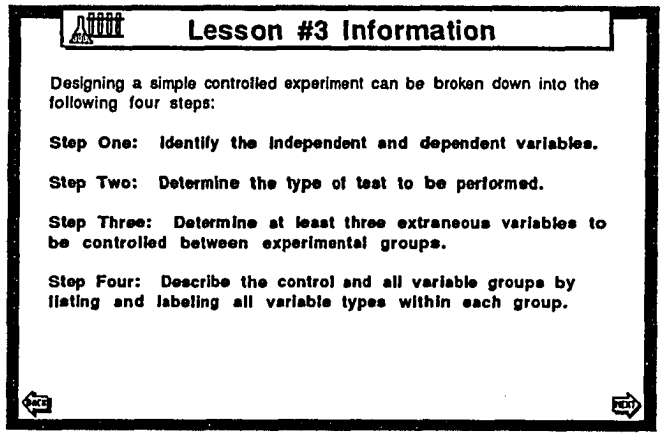
Click on an **extraneous variable** in the control group.

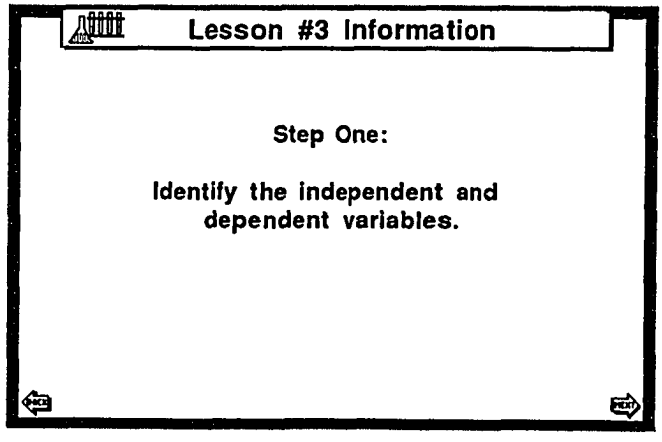








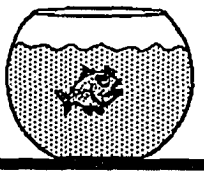




Lesson #3 Information

The first step in designing a controlled experiment is to identify the independent and dependent variables stated in the problem or hypothesis.

Suppose you noticed that the goldfish in your local pet store aquarium seemed to grow much bigger than your goldfish at home. You also noticed that the pet store always plays quiet, relaxing music throughout the day.



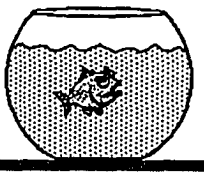
BACK NEXT

Lesson #3 Information

You think about the problem "Why do the pet store goldfish seem to grow much larger than mine?" and you come up with the following hypothesis:

The pet store goldfish grow much bigger than mine because the quiet, relaxing music slows down the fish, making them grow bigger and fatter.

In other words: Quiet, relaxing music makes goldfish grow bigger.



BACK NEXT

Lesson #3 Information

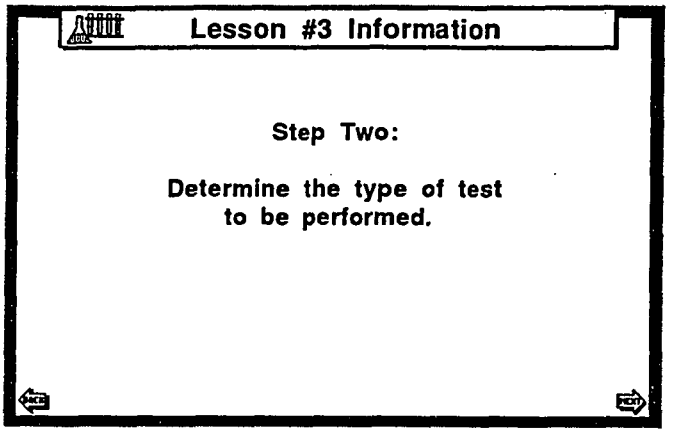
The first step in the designing an experiment to test the hypothesis is to identify the independent and dependent variables. This should be a review for you since you covered this in the previous lesson!

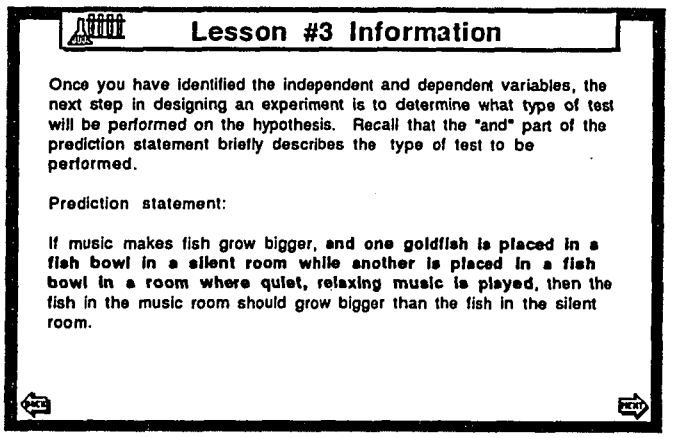
Problem: Why do the pet store goldfish grow larger than mine?

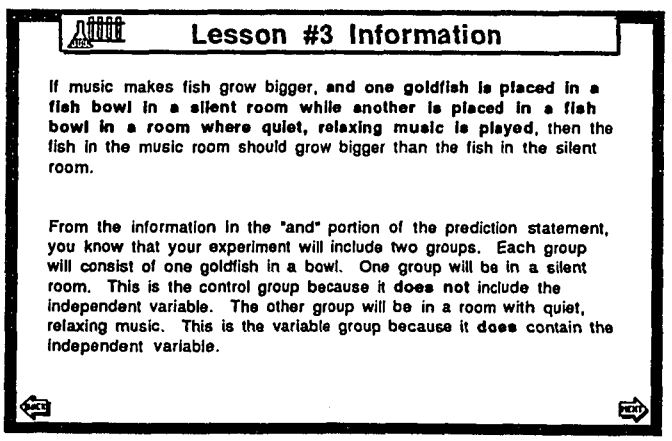
Hypothesis: Quiet, relaxing music makes goldfish grow bigger.

The independent variable would be the quiet, relaxing music, and the dependent variable would be how big the fish grows.

BACK NEXT







Lesson #3 Information

Step Three:

Determine at least three extraneous variables to be controlled between experimental groups.

Lesson #3 Information

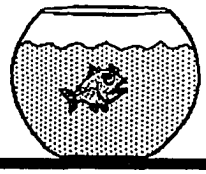
So, now you know the independent and dependent variables along with a brief description of the test or experiment. The next step is to describe the extraneous variables that will be included in both the control and variable groups. Recall that extraneous variables are those variables that might affect the dependent variable...in this case the growth of the goldfish, but you don't want them to affect the two groups differently. These are the variables you will keep exactly the same between groups.

Share with each other some variables that might affect fish growth besides music.

Lesson #3 Information

Hopefully, you came up with some of the following variables:

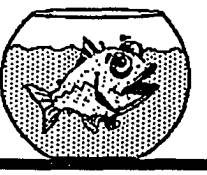
- Size of the fish bowl
- Temperature of the water
- Amount of food per day
- Type of food
- Condition of the water
- Amount of light
- Type of fish
- Age of fish
- Sex of fish



Lesson #3 Information

Hopefully, you came up with some of the following variables:

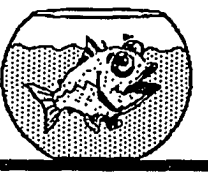
- Size of the fish bowl
- Temperature of the water
- Amount of food per day
- Type of food
- Condition of the water
- Amount of light
- Type of fish
- Age of fish
- Sex of fish



Lesson #3 Information

In this experiment example, the variables that will be controlled include:

- Size of the fish bowl
- Temperature of the water
- Amount of food per day
- Type of food
- Type of fish
- Age of fish
- Sex of fish



Lesson #3 Information

Step Four:

Describe the control and all variable groups by listing and labeling all variable types within each group.

Lesson #3 Information

The last step is simply listing and labeling everything you have done up to now. It is helpful to draw a "T" chart like the one below to help you organize all the information:

Control Group	Variable Group	*Variable Type*
1 Male Goldfish	1 Male Goldfish	Extraneous
60 Days Old	60 Days Old	Extraneous
5 Gallon Bowl	5 Gallon Bowl	Extraneous
75° Water	75° Water	Extraneous
1 gram food/day	1 gram food/day	Extraneous
No Music	Music	Independent
Measure growth	Measure growth	Dependent

BACK NEXT

Lesson #3 Information

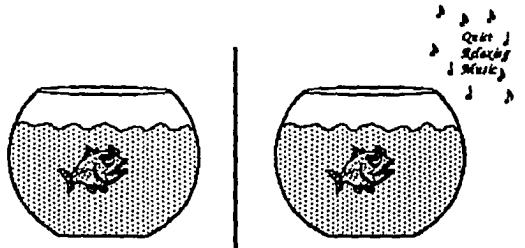
You know you have designed the experiment correctly if your "T" chart includes the following:

- Variable group contains the independent variable stated in the hypothesis
- The dependent variable is the same for both the control and variable groups, and it is stated or implied in the hypothesis
- The groups match the type of test briefly described in the "and" part of the prediction statement
- The main extraneous variables that migh have an effect on the dependent variable are listed, and they are the same for all experimental groups

BACK NEXT

Lesson #3 Information

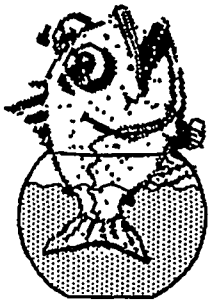
If the experiment is designed properly, any difference in fish growth would be the result of the music, and nothing else.



Control Group | Variable Group

BACK NEXT

Lesson #3 Information



Control Group

Variable Group

Lesson #3 Information

Before you answer some practice problems over this final lesson, you will go through one more example of designing a controlled experiment. Each of the four steps will be followed throughout the process.

The Tire Experiment

Although your neighbors have the exact same type of car that your family has, they claim to get much better gas mileage. Not wanting to live with poorer performance, you decide to inspect their car closely to see if something is causing their car to work better.

Everything looks exactly the same except the tires on their car are a little bigger.

Lesson #3 Information

Problem: Why does the neighbors car get better gas mileage?

Hypothesis: The neighbors car gets better mileage because the tires are bigger. Bigger tires give you better gas mileage.

Prediction: If bigger tires give you better gas mileage, and you put bigger tires on one car and normal size tires on another car, then the car with the bigger tires will get better mileage.

Click on your family's car to give it bigger tires:

Lesson #3 Information

Problem: Why does the neighbors car get better gas mileage?

Hypothesis: The neighbors car gets better mileage because the tires are bigger. Bigger tires give you better gas mileage.

Prediction: If bigger tires give you better gas mileage, and you put bigger tires on one car and normal size tires on another car, then the car with the bigger tires will get better mileage.

Click on your family's car to give it bigger tires:

Lesson #3 Information

Step One: Determine the independent and dependent variables.

Hypothesis: Bigger tires give you better gas mileage.

What is the independent variable in the hypothesis? [Student#1], answer in the box below. When you have finished typing your answer, click on the "Click Me!" button.

Click Me!

Lesson #3 Information

Hypothesis: Bigger tires give you better gas mileage.

What is the dependent variable in the hypothesis? [Student#2], answer in the box below. When you have finished typing your answer, click on the "Click Me!" button.

Click Me!

Lesson #3 Information

Step two involves determining the type of test to be performed.

Look at the prediction statement below. Determine the test to be performed and type it into the box below the statement. Click on the "Click me!" button when you have finished.

Prediction: If bigger tires give you better gas mileage, and you put bigger tires on one car and normal size tires on another car, then the car with the bigger tires will get better mileage.

Click Me!

Lesson #3 Information

Step three in the experimental design process is determining at least three extraneous variables to be controlled between experimental groups.

So, if you are going to have one car with bigger tires and one car with smaller tires, what are some of the other things between the two cars that might affect their gas mileage? These will be the variables kept the same between the two cars during the experiment.

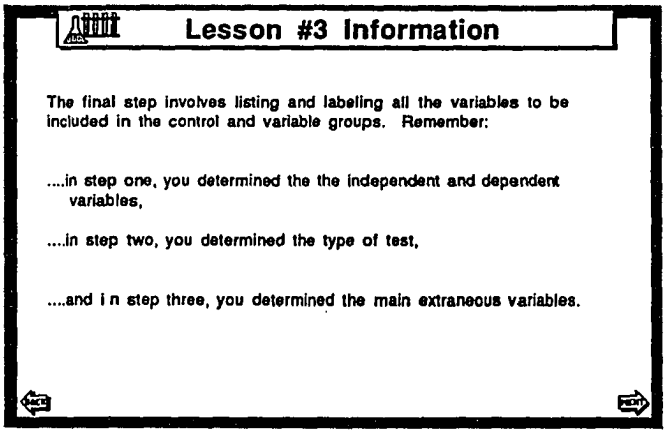
Discuss with your partner at least three extraneous variables before clicking the "next" arrow.

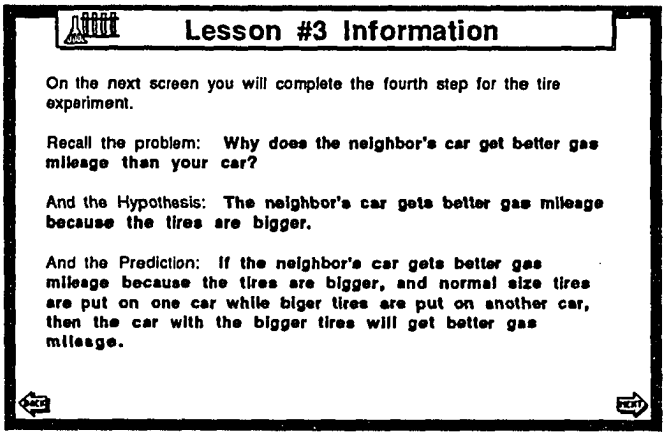
Lesson #3 Information

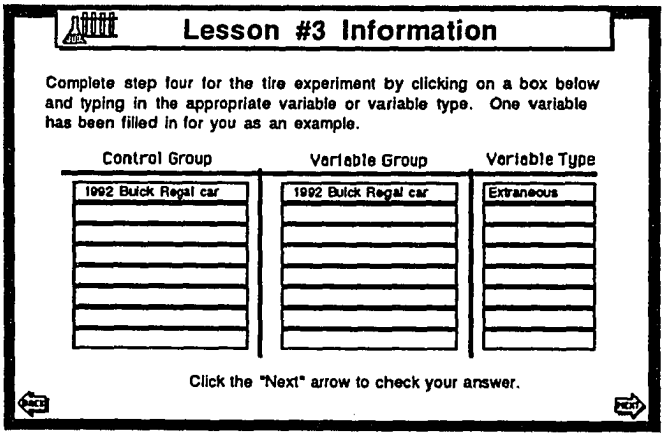
Did your list of extraneous variables include some of the following?

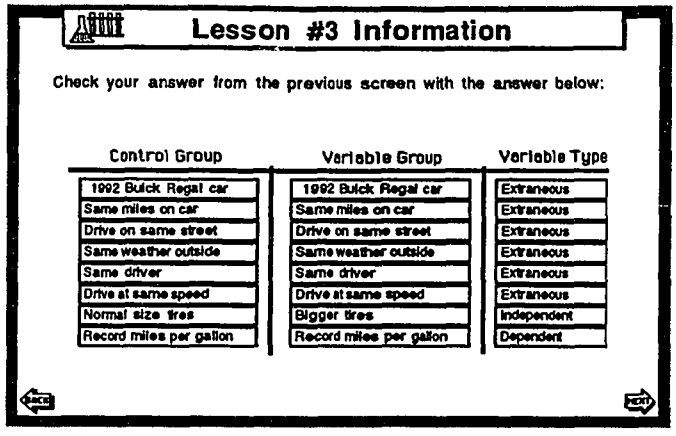
- Type of car
- Type of gas used
- Person driving
- Road driven on
- Amount of miles already driven by the car

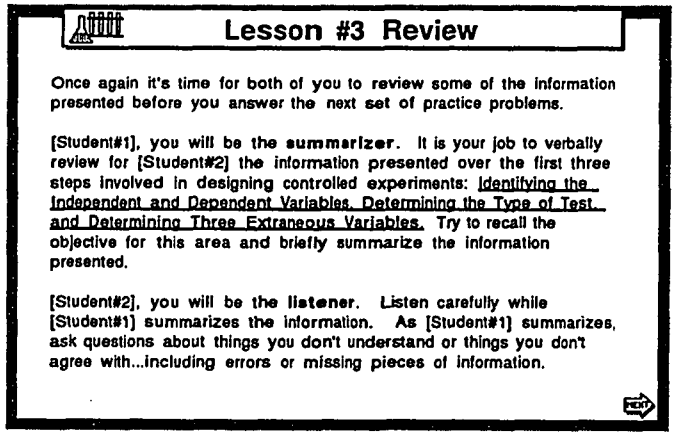
All these variables should be the same for both cars if the test is going to be fair, because all of these variables could have an effect on the gas mileage besides the size of the tires.

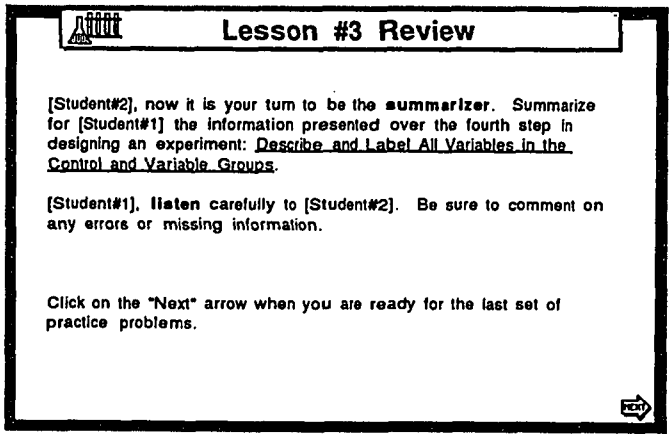


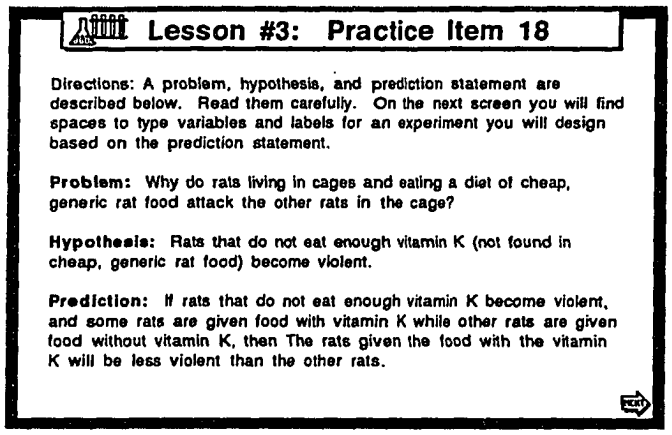


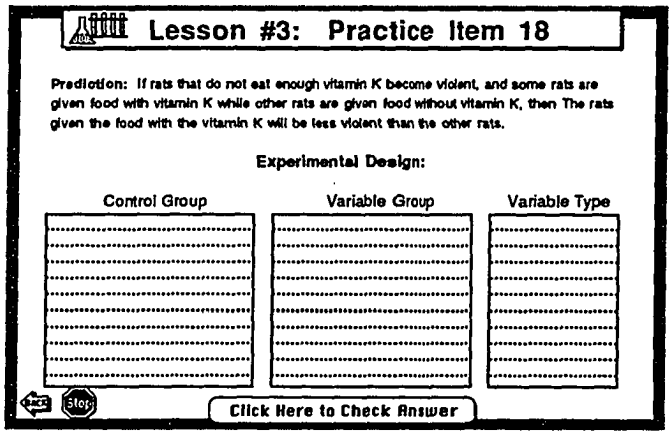


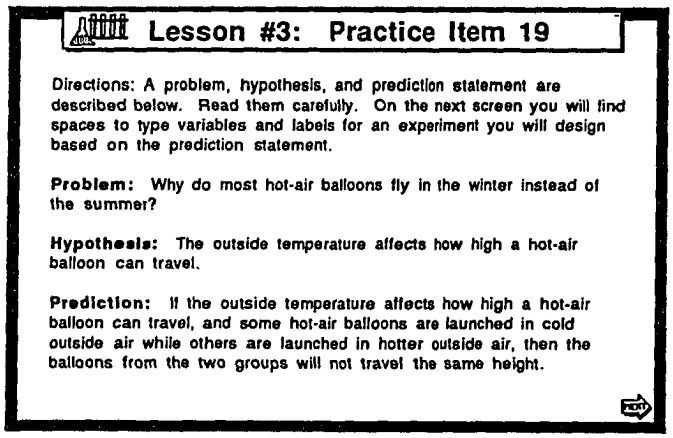


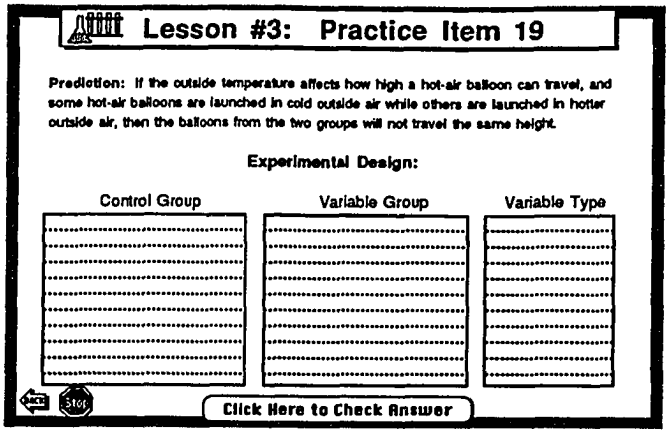


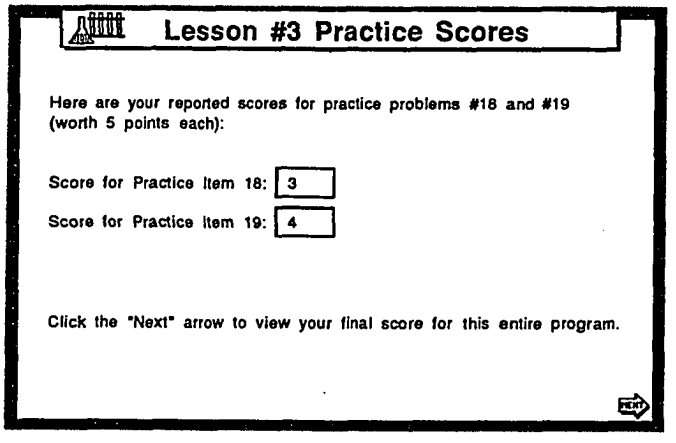


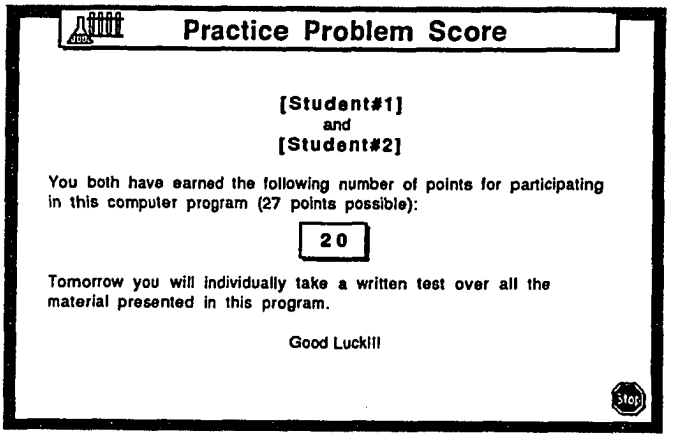


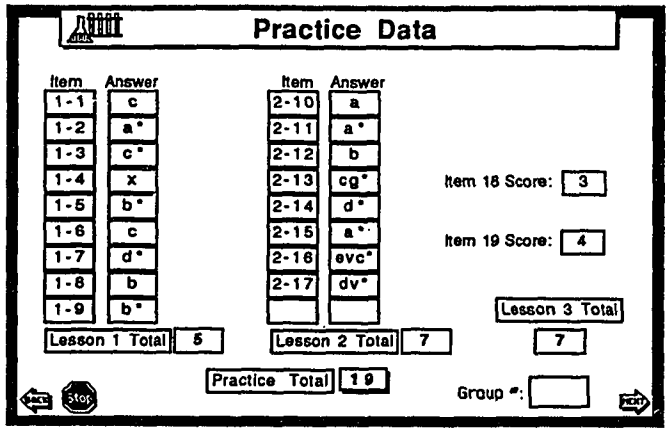


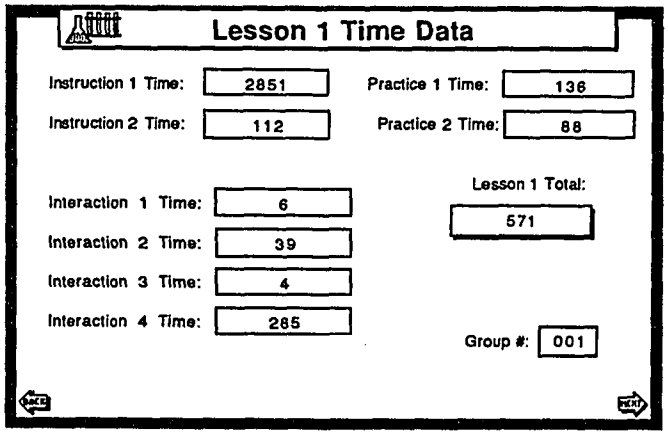


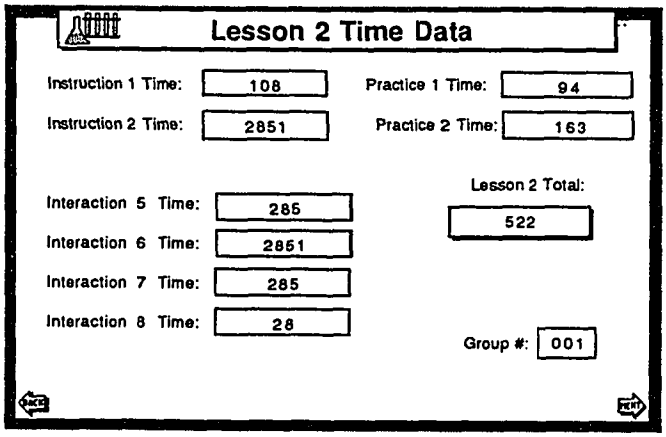


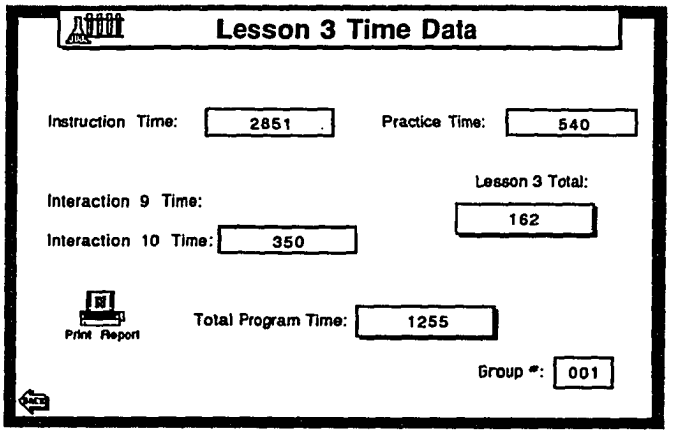


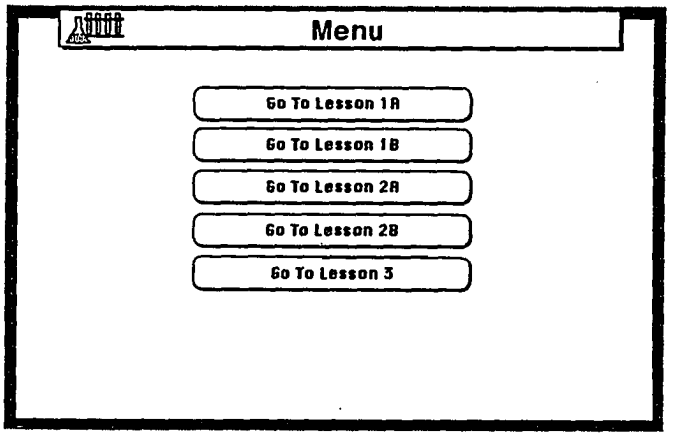












APPENDIX D

POSTTEST

ANSWER SHEET

ANSWER KEY

Designing Controlled Experiments
Test

Answer all the test questions in the spaces provided on your answer sheet!

Label each of the following definitions (1-6) with the term **Experiment, Problem, Observation,** or **Hypothesis** in the space provided on your answer sheet. If a statement does not define any of these terms, write the word **None.**

1. A guess at the answer to a problem, usually based on many observations.
2. Anything you see, hear, smell, touch, or taste.
3. Trying to solve a problem to figure out the truth.
4. A question about one or more observations.
5. A test on a hypothesis to determine if it might be true.
6. A question about the answer to a hypothesis.

Label each of the following statements (7-15) as a **hypothesis, conclusion, observation, prediction,** or **problem.** Record all answers on your answer sheet.

7. Girls do better on tests than the boys in my class.
8. The girls do better on tests than the boys in my class because all the boys are on the football team and they don't have time to do their homework.
9. If girls do better on math tests than boys because all the boys are on the football team and they don't have time to do their homework, and a group of boys and a group of girls are given the exact same amount of time to study, then their math scores should be about the same.
10. Why do the girls do better on tests than the boys in my class?
11. Flower petals have strong odors to attract insects so that pollen will transfer from one flower to another.
12. Based on the data, the hypothesis is not supported.

13. Flower petals have strong odors to scare away those insects that want to eat the entire plant.

14. Why do flower petals have strong odors?

15. If flower petals have strong odors to scare away those insects that want to eat the entire plant, and the smell is removed from a group of flowers on a plant, then the plant should show signs of being eaten by insects

Identify the independent and dependent variables underlined in the following hypotheses (16-18). Each underlined variable is listed on the answer sheet. For each hypothesis, write "**I.V.**" next to the independent variable and "**D.V.**" next to the dependent variable on the answer sheet.

16. The amount of pollution in the air affects the redness of a sunset.

17. The acceleration of a car is affected by which brand of gasoline is used.

18. A person's age affects how well they can see.

Both of the following hypotheses (19-20) contain a clearly stated **independent variable**. Identify the independent variable for each hypothesis and record it in the space provided on the answer sheet.

19. Music has an effect on a plant's growth.

20. The amount of salt in water affects how fast it freezes.

Both of the following hypotheses (21-22) contain a clearly stated **dependent variable**. Identify the dependent variable for each hypothesis and record it in the space provided on the answer sheet.

21. The size a goldfish grows is affected by the size of the bowl.

22. The amount of sleep the night before a test affects the score earned on the test.

23. Below are two set-ups for an experiment testing the hypothesis: "Smoking causes cancer in rats." Write an "**A**" on the answer sheet if group A is the control group, or write "**B**" on your answer sheet if group B is the control group.

Group A: 20 rats, sealed room, 2.0 gallons water per week, 3.0 pound rat food per week, cigarette smoke

Group B: 20 rats, sealed room, 2.0 gallons water per week, 3.0 pounds rat food per week, no cigarette smoke

24. Below are two set-ups for an experiment testing the hypothesis: "Dima-Peep cold medicine prevents chickens from coughing." Write an "**A**" on the answer sheet if group A is the control group, or write "**B**" on your answer sheet if group "B" is the control group.

Group A: 10 male and 10 female chickens, 4.0 pounds chicken feed per week, 2.0 gallons water per day, 25 m X 25 m fenced yard

Group B: 10 male and 10 female chickens, 4.0 pounds chicken feed per week, 2.0 gallons water per day, 25 m X 25 m fenced yard, 10 drops Dima-Peep cold medicine per chicken per day

25. Below is listed the control and variable groups for an experimental design testing the hypothesis "Removing the outer husk on polished rice grains (rice without outer husks) fed to chickens causes the chickens' muscle control to become uncoordinated." Label each variable in the variable group as an independent variable (**I.V.**), dependent variable (**D.V.**), or extraneous variable (**E.V.**). in the spaces provided on the answer sheet.

Control Group	Variable Group
• 20 chickens	• 20 chickens
• unpolished rice (rice with husks)	• polished rice (rice with no husks)
• 5.0 liters water per day	• 5.0 liters water per day
• 25 m X 25 m fenced yard	• 25 m X 25 m fenced yard
• Record number of times chickens fall down	• Record number of times chickens fall down

26. Below is listed the control and variable groups for an experimental design testing the hypothesis "The temperature of a tennis ball affects how high it will bounce." Label the variables in the control and variable groups as an independent variable (**I.V.**), dependent variable (**D.V.**), or extraneous variable (**E.V.**). in the spaces provided on the answer sheet.

Control Group	Variable Group
• One Penn tennis ball	• One Penn tennis ball
• Unheated ball (80° F)	• Ball heated to 140° F
• Dropped from 5 meters	• Dropped from 5 meters
• Record height of first bounce	• Record height of first bounce
• Drop 10 times	• Drop 10 times

27. Listed below are a problem, hypothesis, and prediction statement about goldfish growth. Design an experiment to test the hypothesis by **listing** and **labeling** the variables to be present in the control and variable groups of your experiment. Be sure to include at least 3 extraneous variables in your design. Spaces to record your design are provided on the answer sheet.

Problem: Why are goldfish living in ponds usually much larger than goldfish living in aquariums?

Hypothesis: Goldfish living in ponds are usually much larger than goldfish living in aquariums because algae is floating around in pond water and the goldfish can eat this along with other goldfish-type food.

Prediction: IF goldfish living in ponds are usually much larger than goldfish living in aquariums because algae is floating around in pond water and the goldfish can eat this along with other goldfish-type food, AND some goldfish are raised in "clean" aquariums that have regular filtered goldfish water while other goldfish are raised in aquariums that have algae present in the water, THEN the goldfish in the algae aquariums should grow larger than the goldfish in the "clean" aquariums.

28. Listed below are a problem, hypothesis, and prediction statement about math scores and potato chips. Design an experiment to test the hypothesis by **listing** and **labeling** the variables to be present in the control and variable groups of your experiment. Be sure to include at least 3 extraneous variables in your design. Spaces to record your design are provided on the answer sheet.

Problem: Why do most large students do better on math tests than most skinny students?

Hypothesis: Most large students do better on math tests than most skinny students because large students eat more potato chips than skinny students before a math test.

Prediction: IF most large students do better on math tests than most skinny students because large students eat more potato chips than skinny students before a math test, AND a group of large and skinny students are fed chips before a math test and a different group of large and skinny students are not fed chips THEN the students in the group fed the chips will do better on the math test regardless of their size.

Name: _____ Group #:_____

Designing Controlled Experiments Test
Answer Sheet

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. Amount of polution: ___

    Redness of a sunset: _____
17. Acceleration of a car: _____

    Brand of gasoline:_____
18. Age: _____

    How well they can see:_____
19. I.V. _____
20. I.V. _____
21. D.V. _____
22. D.V. _____
23. _____
24. _____
25. Variable Group

    _____ 20 chickens

    _____ polished rice (rice with no husks)

    _____ 5.0 liters water per day

    _____ 25 m X 25 m fenced yard

    _____ Record number of times chickens fall down

26.

Control Group	Variable Group
_____ One Penn tennis ball	_____ One Penn tennis ball
_____ Unheated ball (80° F)	_____ Ball heated to 140° F
_____ Dropped from 5 meters	_____ Dropped from 5 meters
_____ Record height of first bounce	_____ Record height of first bounce
_____ Drop 10 times	_____ Drop 10 times

27.

Control Group	Variable Group	Variable Type

28.

Control Group	Variable Group	Variable Type

Designing Controlled Experiments Posttest Answer Key

(point values for each question in parentheses)

1. *Hypothesis (1)*
2. *Observation (1)*
3. *None (1)*
4. *Problem (1)*
5. *Experiment (1)*
6. *None (1)*
7. *Observation (1)*
8. *Hypothesis (1)*
9. *Prediction (1)*
10. *Problem (1)*
11. *Hypothesis (1)*
12. *Conclusion (1)*
13. *Hypothesis (1)*
14. *Problem (1)*
15. *Prediction (1)*
16. Amount of polution: *I.V.*

    Redness of a sunset: *D.V.*

    (1 point for both correct)
17. Acceleration of a car: *D.V.*

    Brand of Gasoline: *I.V.*

    (1 point for both correct)
18. Age: *I.V.*

    How well they can see: *D.V.*

    (1 point for both correct)
19. I.V. *Music (1)*
20. I.V. *Amount of salt (1)*
21. D.V. *Size of goldfish (1)*
22. D.V. *Score earned on test (1)*
23. *B (1)*
24. *A (1)*
25.

Variable Group	
E.V.	20 chickens
I.V.	polished rice (rice with no husks)
E.V.	5.0 liters water per day
E.V.	25 m X 25 m fenced yard
D.V.	Record number of times chickens fall down

(1 point for all correct labels)

26.

Control Group	Variable Group
E.V. One Penn tennis ball	*E.V.* One Penn tennis ball
_____ Unheated ball (80° F)	*I.V.* Ball heated to 140° F
E.V. Dropped from 5 meters	*E.V.* Dropped from 5 meters
D.V. Record height of first bounce	*D.V.* Record height of first bounce
E.V. Drop 10 times	*E.V.* Drop 10 times

(1 point for all correct labels)

27.

Control Group	*Variable Group*	*Variable Types*
Non-algae food	*Algae*	*I.V.*
Measure fish size	*Measure fish size*	*D.V.*
		3 E.V.

1 point for proper I.V. and D.V. for both labeled groups
1 point for 3 E.V. the same for both groups

28.

Control Group	*Variable Group*	*Variable Types*
No Chips	*Chips*	*I.V.*
Record math test scores	*Record math test scores*	*D.V.*
		3 E.V.

1 point for proper I.V. and D.V. for both labeled groups
1 point for 3 E.V. the same for both groups

APPENDIX E

ATTITUDE SURVEY

Name: _____

Group #:_____

Attitude Survey

The following statements refer to your feelings about participating in the computer program "Designing Controlled Experiments". Circle the number that best describes your level of agreement with each statement. Be as honest and sincere as possible. Your responses will not be graded for points.

1 = Strongly Agree
2 = Agree
3 = Disagree
4 = Strongly Disagree

1. The computer program was interesting.	1	2	3	4
2. I tried hard to understand the information presented in the computer program.	1	2	3	4
3. My partner tried hard to understand the information presented in the program.	1	2	3	4
4. I concentrated on learning throughout the entire program.	1	2	3	4
5. My partner concentrated on learning throughout the entire program.	1	2	3	4
6. The information presented in this program was easy to understand.	1	2	3	4
7. I enjoyed working with a partner.	1	2	3	4
8. I am confident that I will do well on the final test.	1	2	3	4
9. I would like to learn more about designing experiments.	1	2	3	4
10. I would like to work with a partner again and do another science lesson on the computer.	1	2	3	4

APPENDIX F

INTERACTION OBSERVATIONS DATA SHEET

Interaction Observations Data Sheet

Group #: _____ Version: C NC Group Type: LL HH LH

Week: 1 2 Day: 1 2 Hr::_____

Student #1: _____ Sex: M F Level: L H

Student #2: _____ Sex: M F Level: L H

Interaction Measure	Student #1	Student #2
Summarized during interaction screens		
Explained during interaction screens		
Identified errors or missing pieces of information during interaction screens,		
Asked for clarification, explanations, or other help during interaction screens		
Gave solicited clarification, explanations, or other help during interaction screens		
Gave unsolicited help during interaction screens		
Checked for partner's understanding during interaction screens		
Encouraged partner during interaction screens		
Off-task during interaction screens		