A STUDY OF COMPUTER-ASSISTED INSTRUCTIONAL STRATEGIES AND LEARNER CHARACTERISTICS

by

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A STUDY OF COMPUTER-ASSISTED INSTRUCTIONAL STRATEGIES AND LEARNER CHARACTERISTICS

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ABSTRACT

This study was undertaken to investigate the use of computer-assisted instruction as an instructional laboratory. The concept of an instructional logic was defined as an algorithm followed by the computer program for each instructional unit. This step-by-step logic was repeated for each instructional unit but with different content.

This procedure permitted the controlled manipulation of the variable of correctional feedback. Three forms of correctional feedback were defined by varying the information content of the feedback. These were response-sensitive correctional feedback, response-insensitive correctional feedback and no correctional feedback (only that the answer was incorrect).

The interaction of correctional feedback with selected learner characteristics was examined as well. These learner traits were mathematical ability, prerequisite knowledge
and state anxiety. The effect of correctional feedback and its interaction with these variables was examined.

Subjects of the study were a representative sample of sixty-three preservice elementary school teachers from five sections of a mathematics course given in a large education faculty. These subjects were randomly assigned to the three treatment conditions, although they selected the CAI experimental periods in which they would participate. The test of mathematical ability used was the Cooperative Sequential Test of Educational Progress, Mathematics Form 2A (STEP). The state anxiety instrument used was the State-Trait Anxiety Inventory (STAI) and the five item short form used by O'Neil (1972) was administered twice. The eighteen item posttest was constructed by the experimenter and the measure of prerequisite knowledge used was a nine item prelesson with a possible mark of 0, 1 or 2 on each item.

The mathematics lesson was a topic in introductory calculus dealing with the concept of derivative. The topic was treated from a physical point of view, using concepts of distance, speed and time to illustrate the mathematical concepts. The main objectives were to show that the derivative is a limit and to show how to use this limit definition to calculate the derivative of a function at a point.
The CAI lesson was programmed using an author language developed by the experimenter as a vehicle for implementing the instructional logic and varying the correctional feedback. The language is limited in use but has the advantage of requiring essentially no computer experience of an instructional designer. The main limitation of the language as implemented at the University of British Columbia is the cost, which limited the sample size in this experiment.

The results of the study were generally in the expected direction but the effects were not as pronounced as had been hypothesized. The most important finding was the significant difference in proportion of errors on the main lesson between the response-insensitive \( T_2 \) and no correctional feedback \( T_3 \) groups. The importance of this finding was then increased by the significant relationship found between immediate learning and proportion of errors with the effect of learner traits and treatment effects statistically removed.

The most effective variable in predicting performance in the experiment was mathematical ability and its effect was statistically controlled when testing the effect of the other variables. Prerequisite knowledge was also important in predicting performance and was statistically controlled as well. State anxiety was significant in predicting
proportion of errors but not response latency. However, significant treatment-by-A-State interactions were observed for posttest and for response latency.

The three treatment groups differed in the expected direction on most of the important variables but the differences were not statistically significant. In particular, the A-State levels for the three groups were ordered as expected, but the differences were not large enough to cause the hypothesized interactions.

The results of the study partially supported the hypothesis of the important role of correctional feedback in instruction and its interaction with individual traits of the learner.

Finally, the variable of state anxiety was examined and it was found that higher levels of state anxiety led to longer response latencies. Also, state anxiety increased when no correctional feedback was provided to the students as well as when the content became more difficult. This finding confirmed the expected relationship between state anxiety and task difficulty.
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CHAPTER I

THE PROBLEM

Overview of the Problem

One goal of this study was to develop a methodology which would demonstrate the power of utilizing a computer to assist in the development of models for instruction. This methodology was developed in the context of the computer acting as personal tutor for individual students. By using the computer in this manner, a laboratory to study instruction was created. This laboratory permitted the gathering of reliable and valid data under carefully controlled and replicable conditions, using materials having some educational significance to the students.

The major goal of this study was to apply the methodology to a research study which would make a contribution to the area of instructional theory. A particularly controversial problem was examined: the role of correctional feedback in the instructional process.

Several steps were involved in the attainment of these two goals. First, the methodology was developed. A computer language was written by the experimenter to
implement a particular instructional logic which permitted lessons to be programmed for the computer by novice computer users. The language implemented a particularly flexible teaching logic which was followed by the computer many times during an instructional session. The second step involved the development of a teaching unit (lesson) dealing with a topic in elementary calculus. This unit is presently being used in an altered form as a tutorial aid by college students in an introductory physics course (Kalman et al., 1972).

The third step consisted of developing an organizational scheme for studying the instructional process using the above methodology. Several variables in the organizational scheme were examined. These variables reflected some unresolved problems in the literature on instruction. The effect of correctional feedback on learning was assessed by manipulating this variable in a controlled experiment. The interaction of correctional feedback and selected learner characteristics was also examined. The use of the computer permitted the variable of correctional feedback to be examined under controlled conditions and provided data to clarify the effects of this variable on learning.
Although the experiment focused on a particular aspect of the instructional process, the methodology that was developed could be used by others to examine other variables of interest in the organizational scheme.

Introduction to CAI

The term computer-assisted instruction (CAI) describes an instructional situation where a student works at a terminal connected electronically to a computer. An instructional program is stored in the computer. The program comprises the complete package of information, instructions and logic with which the student will interact during his learning session. The terminal, which serves as the interface between the computer and the student, usually consists of a typewriter keyboard and either a paper roll of TV-like screen, called a cathode-ray tube, upon which the communications to and from the computer are displayed. In order to have CAI, the computer must actually instruct the student through the program and not just be used as a tool to assist in the solution of problems or the retrieval of information. By definition, there must be two-way human-to-computer communication in which there occurs a stimulus-response-feedback relationship producing learning (Silvern, 1967).
Atkinson (1968a) commented that in recent years a great number of articles and news releases dealing with CAI has been published. He observed that few of such reports are based on substantial experience and research, but that the majority consist of vague speculations and conjectures with little, if any, data or real experience to substantiate the claims for CAI. Bundy (1967) noted that, with few exceptions, available information about CAI consists of descriptive accounts of what a particular institution is doing, or short statements of research findings. He also noted that CAI has not reached the kind of maturity that programmed learning has attained as an area of endeavor. Some recent CAI work in the last two years indicates that this situation is changing (e.g. Judd et al., 1973; Keats and Hansen, 1972; O'Neil, 1972b; Tobias, 1973).

Suppes (1966) distinguished three levels of interaction between the student and the computer program. At the most superficial, and also the most economical level, are drill-and-practice systems. At this level, the student is presented with examples on which he needs practice, and drilled on those to which he fails to respond correctly (Suydam, 1969). Instructional programs
that fall under this heading are merely supplements to a regular curriculum taught by a teacher.

The next level of interaction includes tutorial systems which are more complex than drill-and-practice systems. The computer-teacher initiates the question, for which answers are stored in advance and a restricted kind of dialogue between the student and the computer is achieved. Suppes (1966) claims that the aim here is to individualize instruction and to free the teacher from many classroom responsibilities so that he will have more time to individualize his own instructional efforts.

At the third and deepest level of student-computer interaction are systems that allow a complex dialogue between the student and the computer (Suppes, 1966). Dialogue systems exist only as rudimentary prototypes. Before this level of interaction can be achieved, the computer will require the capability of interpreting any response and question given by the student, either in writing or orally.

A search of the literature indicated that there are three major arguments used in support of CAI. These are not independent of one another, but they do serve to indicate the major views of CAI which are currently prevalent. The first argument in support of CAI is that
CAI is a medium used to individualize instruction. Suppes (1966) claimed that this is the single most important application of CAI. He wrote that the principal obstacles to widespread implementation of CAI are not technological but pedagogical: how to devise means of individualizing instruction and how to design a curriculum that is suited to individuals instead of groups.

Many researchers (Atkinson, 1968b; Bundy, 1967; Seidel, 1969; Stolurow, 1962) have claimed that a second application of CAI provides the most valuable contribution to education. These writers refer to the use of CAI as a laboratory for research in learning and instruction. With the computer, it is possible to be quite explicit about a teaching method and to reproduce the conditions as often as desired. Added to this is the capability of the computer for storing and manipulating data. The data can be used by the researcher to modify the presentation in progress and the data can be manipulated later in many different ways to provide information about the instructional variables under study. Variables such as errors in learning, response latency and effectiveness of diagnostic materials can be examined in detail. Stolurow (1962) and Atkinson (1968c) predicted that the computer will contribute to the
emergence of one or more theories of instruction supported by reliable and valid data.

A third argument used to support CAI is that it is a medium which can change the role of the teacher and the school environment. Computers have been used to a limited extent for direct instruction in a few selected schools in the United States of America (Atkinson, 1968d; Pressman, 1970; Suppes, 1966). Stansfield (1968) cautioned that CAI is not ready for the schools and that the schools are not ready for CAI. Hicks and Hunka (1972) made the following assumptions about CAI:

**Assumption I.** Computer-assisted instruction will surely come into general use in the schools probably within the next decade, and possibly before either the schools or manufacturers of CAI systems can ensure its wise use (1972, p. 69).

**Assumption III.** Computer-assisted instruction is capable of becoming a widely used, versatile and effective educational tool, but it must overcome many handicaps impeding its development (1972, p. 23).

Before this application of CAI becomes widespread, factors such as cost-effectiveness and acceptance of CAT by school personnel remain to be solved.

**Organizational Scheme for CAI**

This author has proposed an organizational scheme in Figure 1 for research into a particular area of CAT.
The scheme assumes that the important role of CAI at the present time is that of an instructional laboratory, although questions relating to individualizing instruction may also arise from the model.

The organizational scheme shown in Figure 1 suggests that a learner interacts with a CAI lesson and exhibits behaviour which is observable and from which one can make inferences about his learning. The basic assumption underlying the model is that certain learner variables and certain CAI lesson variables will interact to produce differential effects on the output variables.
Learner variables have also been called personological variables (Bracht, 1970) and these may be considered as measures of individual student characteristics. Cognitive variables can be considered as general or specific intellectual abilities of the learner. Examples of cognitive variables are IQ, mathematical ability and prerequisite knowledge. Personality variables refer to variables such as attitudes, anxiety or motivation. Psychomotor variables refer to the manipulative or motor-skill area, e.g., typing speed and accuracy.

A CAI lesson comprises three discernible variables. The instructional variables refer to those variables which characterize the instructional strategy, not the content, and these can be manipulated by the instructional programmer. Examples of instructional variables are step size, type or frequency of feedback and type of branching. The machine variables refer to both hardware and software variables which affect the CAI lesson. Hardware variables involve characteristics of the computer terminal used, typing rate for example. Software variables are characteristics of the CAI author (programming) language used to write the lesson, branching capabilities for example. Rogers (1966) cautioned that
these computer characteristics can impose severe limitations upon both the materials which can be presented to the learner and the responses which the learner can be required and allowed to make. The final dimension of the CAI lesson refers to the nature of the subject being taught. Hicks and Hunka (1972) suggested some subject matter distinctions: loosely structured versus highly structured, experiential versus rational, value-laden versus neutral. Suppes (1966) remarked that well-structured subjects such as reading and mathematics can easily be handled by tutorial as well as by drill-and-practice systems.

The output variables represent observable behaviors exhibited by the learner and from which learning may be inferred. These can be considered as either process or product variables. Process variables, such as the number or type of errors made during learning and response latency, give an indication of the student's performance during the lesson. These may be considered as representing either accuracy (errors) or efficiency (latency) of the student's learning process. Product variables, such as immediate learning, retention, transfer and attitudes, are the result of what the student has gained from the completed CAI lesson.
Discussion of the Problem

The present study made use of the organizational scheme described earlier to examine the effect on the output variables of learner variables, CAI lesson variables and their interaction. The relationship between the process and product variables at the output of the model was also examined.

In the CAI lesson component of the model, instructional variables were under consideration and three different instructional strategies were examined. Stolurow (1969) explained that strategy can be thought of as a set of rules and the first task of the teacher or educational theorist is to reduce the strategy to an explicit algorithm so that it can be programmed for implementation by a CAI system. Sherman (1971) pointed out that most of the time required to construct conversational exchanges between student and the computer is taken up by two tasks: designing the instructional logic and programming the conversational network. He suggested that by utilizing a specific predetermined instructional strategy, which he called a template, the time spent on the second task could be reduced substantially. The reason for this is that the template, which may be compared to a standard subroutine or
procedure in computational programs, allows the lesson designer to merely supply the content and not the logic elements to the CAI lesson. A lesson consists of a particular inter-connection of one or more of these templates. Two templates were designed and implemented for this study: one for the main lesson and one for the prelesson. These templates are discussed in Chapter III.

The three instructional strategies considered in this study were three variations of the template designed for the main lesson. The variable which distinguished these strategies from one another was the extent of knowledge of results or, more specifically, the correctional feedback given to the student after each incorrect response. The correctional feedback given in the first instructional strategy was characterized as response-sensitive, i.e., correctional feedback given to the student was appropriate to the type of error that he made in his response. The second strategy was response-insensitive, i.e., the correctional feedback given consisted of a hint which was constant regardless of the nature of the error made on that response. The final strategy involved informing the student whether his response was correct or not, but no correctional feedback or hint was given. The third strategy served as a control condition since no
assistance was provided to the student when he responded incorrectly.

Suppes (1966, 1967) concluded that there is conflicting evidence regarding the effects of immediately informing the student each time he makes a mistake. He stated that a central weakness of traditional psychological theories of reinforcement is that too much of the theory has been tested by experiments in which the content of the information transmitted in the feedback procedure is essentially very simple. As a result, the information content of feedback has not been sufficiently emphasized in theoretical discussions.

Many instructional systems or theories contain knowledge of results as a major component although the precise roles of this variable are unclear. Stolurcow (1969) and Morrill (1961) noted that although knowledge of results appears to be effective in the learning process, this problem contains many facets which need empirical study. Along these lines, Gilman (1967) wrote that his results suggest that less elaborate correctional feedback procedures are as effective as the more elaborate prompting, response-contingent feedback, and overt-correction procedures. He suggested that his results should be checked with other subject matters and other students to
establish their degree of generality. The present study examined the knowledge-of-results variable under controlled conditions made possible by the use of CAI and provided empirical data to clarify the effect of this variable.

Suppes (1967) pointed out that a troublesome issue has arisen in recent research. Should different kinds of reinforcement, of which knowledge-of-results may be one kind, and different sorts of reinforcement schedules be given to children with different personalities? This issue relates to the problem of individualizing instruction.

Bracht (1970) suggested that it is possible that no single instructional process provides optimal learning possibilities for all students. However, Bundy (1967) pointed out that to date we still do not understand the learning process sufficiently to make truly self-adaptive learning programs. Bundy (1967) stated that we might be able to make self-adaptive learning programs in the future and the vehicle for accomplishing this may well be CAI, viewed not as an instructional tool, but as an instructional laboratory.

The present study contributed to an understanding of the instructional process by examining aptitude-treatment interactions (ATI). The goal of research on ATI is to find significant interactions between alternative
treatments and individual characteristics of the learner (Bracht, 1970). Subsequently, alternative instructional programs may be developed so that optimal educational benefits are obtained when students are assigned to the alternative programs.

Gentile (1967) emphasized that if it is claimed that adapting to individual differences through CAI would improve some aspect of learning, then parametric studies of variables considered to be important should be undertaken. He found that these parametric studies are scarce because almost all of the funds allotted to CAI projects are being spent on the development of courses or equipment to the exclusion of research on teaching-learning variables, where research is needed most. Dick (1965) noted that the matter of personality-computer interaction remains to be studied. This dissertation study focused on the instructional variables in the CAI lesson and their interaction with selected characteristics of individual learners.

The learner characteristics examined in this study fell into two of the three categories in the model, cognitive and personality. Psychomotor variables were not considered. The cognitive variables were mathematical
ability and prerequisites required for the main lesson. These cognitive variables ranged from general to specific in terms of their relationship to the content and skills required for the CAI lesson. The personality variable under consideration was anxiety. O'Neil et al. (1969a,b; 1972a,b) and Spielberger (1972) examined the effect of anxiety in a CAI context and found significant effects on student performance. They found a disordinal interaction between state anxiety and difficulty of the material presented in the CAI lesson. O'Neil (1972a) pointed out that some studies in the literature have suggested that the relationship between anxiety and learning is different for men and women. This issue was not considered in this study but a representative sample of students was employed to increase the generalizability of the results.

The relationship between the process and product variables is important. If a well-defined relationship exists, then process variables such as errors or latencies may be utilized to make decisions during learning in order to maximize the product variables of learning. This latter question was also examined in the present study.

The questions under consideration in this study appear to be important theoretical issues. An important
practical reason exists as well for examining the instructional variable of correctional feedback. The issue is a cost-effectiveness one. Rogers (1968) estimated that approximately 100 hours of analysis, programming and editing efforts are required to produce programmed instructional (PI) material which occupies the student for one hour. He estimated that one or two orders of magnitude separate the CAI lesson from the PI lesson in terms of the time required for production of a lesson. A major portion of the time required in developing a CAI tutorial lesson is spent in anticipating all possible student responses and providing response-sensitive correctional feedback. The computer software required becomes more complex and computer execution time, and cost, increase if this response-sensitive correctional feedback is implemented. If this instructional variable or its interaction with learner characteristics has no effect on the output variables in the model, then the time, effort and extra cost required to include this feature in the CAI lesson are being poorly spent. Bracht (1970) advised that experimenters should begin to formulate hypotheses about ATI with administrative factors, such as cost, in mind. The results of this study have cost-effectiveness implications because the
costs for providing the three types of feedback range from expensive to inexpensive.

Statement of the Problem

The specific tasks proposed for this dissertation were:

1. Development of an organizational scheme for research into CAI as an instructional laboratory.

2. Design and implementation of an empirical study to examine several variables in the organizational scheme. The instructional variable under consideration was correctional feedback. Its interaction with the learner variables of anxiety, prerequisite knowledge and mathematical ability was examined.

3. Development of a CAI author language permitting a high degree of response-sensitive feedback to be supplied to the student. This language served as a vehicle for the study and implemented a particular instructional logic, permitting data regarding the student's performance to be recorded for subsequent analysis.

4. Development of a CAI module dealing with some
elementary calculus concepts and programmed using the above-mentioned author language. The module included a CAI prelesson dealing with the prerequisites identified for the main lesson.

Research Questions

The several terms which were used in the following research questions are explained below. The learning process variables were proportion of errors, i.e. total errors divided by total responses, and average response latency. The learning product variable was immediate learning, as measured by a posttest. Because of the nature of the instructional logic used in this study, it was felt that proportion of errors would reflect performance better than total errors. The reason for not using total errors was that two errors of the same type would cause the computer to produce the correct answer and would end that instructional unit. Therefore, a student who immediately made two similar errors in a row would terminate that instructional unit without being seriously penalized, even though he had not produced the correct response. The use of proportion of errors corrected this situation. The average latency variable was obtained by calculating the average of the total response latencies for all instructional units. It was felt that total latency
on an instructional unit would better reflect performance than the latency for the first response on that unit. The reason for this is that total latency reflected the effect of the correctional feedback given during that unit.

The research questions were:

1. What is the effect of correctional feedback on the learning process and product?

2. What is the effect of correctional feedback on the learning process for students with different levels of anxiety?

3. What is the effect of correctional feedback on the learning process and product for students with different levels of prerequisite skills?

4. What is the effect of correctional feedback on the learning process and product for students with different levels of mathematical ability?

5. What is the relationship between the learning process variables and the product variables, independent of the effect of the other variables, i.e. anxiety, prerequisite knowledge, mathematical ability and treatment?
Importance of the Study

This study was important because of its contribution to several different areas of knowledge.

The use of CAI as a laboratory to study the instructional process has been discussed. An organizational scheme for CAI as an instructional laboratory has been developed and several aspects of the model are under consideration. Some empirical evidence was provided regarding the effects of correctional feedback on learning under carefully controlled conditions made possible by the use of CAI. Higgins (1973) suggested that one of the variables with greatest potential for contributing to the design of effective instruction is the amount of information contained in the feedback stimulus. The resolution of this controversial issue has theoretical significance for instructional theory, practical significance for classroom instruction and implications for subsequent development of CAI software and lessons.

The area of individualized instruction is currently receiving much attention from educators. A pressing need exists to devote more research activity to the study of interaction between the conditions of instruction and the nature of the learner (Sutter and Reid, 1969). This study examined several learner variables and their interaction with the different instructional strategies. The results would have implications for individualized instruction
since the presence of significant disordinal interactions makes the assignment of individuals to different instructional treatments desirable in order to produce optimal learning for individual learners.

The variable of anxiety is currently receiving much attention in the literature and empirical evidence is required to further develop the State-Trait Anxiety Theory (Spielberger, 1971). This study also contributed to this area by clarifying some of the effects of anxiety on learning.

The relationship between the process variables, such as errors during learning and response latency, and the product variables, such as immediate learning, is important because of the possibility of using the learning process variables to optimize the learning product for individuals. This optimization could be accomplished by basing instructional decisions on these process variables during learning.

An important contribution was the development of a methodology which implemented the concept of CAI as a laboratory to study learning and instruction. The methodology used in this study may be utilized by others or may serve as a model for other researchers to follow in the development of new methods of applying the computer to the solution of educational problems.
CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH HYPOTHESES

Introduction

This chapter contains a survey of the literature related to the areas under consideration in this study. The topics included are: Knowledge-of-Results, State-Trait Anxiety, Aptitude-Treatment Interactions and Tutorial CAI.

Literature on Knowledge of Results

Annett (1964, p.280) defined knowledge-of-results as "... knowledge which an individual or group receives relating to the outcome of a response or group of responses."

Higgins (1972) categorized feedback into three common forms that provide different amounts of information. The three forms were knowledge-of-results (KR), knowledge-of-correct-response (KCR) and instructional feedback.

Knowledge-of-results, the form containing the least information, indicates only whether a response is correct or incorrect. If the response is incorrect, knowledge-of-results does not indicate what the correct response is. Knowledge-of-correct-response differs from knowledge-of-results in that knowledge-of-correct-response always
indicates the correct response. Instructional feedback, the form containing the most information, indicates the correct response and provides an explanation of why that response is correct. Higgins (1972) wrote that it appears from the research literature that potential contributions to the design of effective instruction can be generated by research efforts contrasting the effects of various combinations of the above forms of feedback.

Higgins (1972) pointed out that one factor influencing the effectiveness of feedback is the nature of the learner. Specifically, it appears that feedback is more effective when the learner possesses a low level of competence with regard to the instructional task.

Annett (1964) observed that probably the biggest issue in the area of feedback is that of motivation versus information. He concluded from his study of the area that the information content rather than the motivation content of feedback is important to learning while motivation content of feedback is an important variable in performance. However, in his recent book (1969, p.169), Annett wrote:

... to say that knowledge-of-results provides motivation is misleading. The so-called incentive function of knowledge-of-results seems to involve both providing the subject with a performance standard to aim for and information necessary for corrective action.
Annett (1964) concluded that none of the generalizations which have been made in the past about knowledge-of-results can be accepted at face value.

Annett (1969) reviewed the psychological literature in the area of feedback. He concluded that the role of results or consequences in behaviour seems to have been underrated. He thought of knowledge-of-results as the manipulation of an external feedback loop relating to certain aspects of a subject's performance.

Morrill (1961) reached essentially the same conclusion as Annett when he stated:

Because of their controvertible results, the above studies demonstrate that, although immediate feedback appears to be effective in the learning process, this problem contains many facets which need more empirical data.

Higgins (1972) pointed out that the research most frequently cited in describing the role of feedback in instruction has come from three sources of experimentation: laboratory studies of human learning, studies employing existing conventional instructional materials which in their original form do not require overt learner response, and investigations with programmed instructional materials. Most research from the first two sources has very limited applicability to the design of instructional materials because of the difference between the materials and
procedures employed in these studies and those used in systematically designed instruction, such as in the present study. Higgins (1972) pointed out that in most laboratory studies of human learning, the learner receives no instruction before being asked to respond. He stated that this procedure is ineffective instructionally when contrasted with procedures in which the learner receives initial instruction designed to enable him to respond correctly. Higgins (1972) feels that the limited applicability to instructional design of laboratory studies and of investigations involving conventional materials leaves the studies using programmed instructional materials as the basis for useful research up to this point in time. Obviously, studies utilizing CAI fall into this category and may actually provide stronger evidence due to increased control of extraneous variables.

The variable of instructional feedback is an important component of most instructional models (Stolurow, 1971; Merrill, 1971). Stolurow (1971) defined three critical system functions in his instructional approach:

a. The cue function provided by the program of instruction, i.e. the stimulus to which each criterion response is attached;
b. the motivation function, i.e. eliciting the desired performance; and

c. the feedback function, i.e. providing immediate knowledge-of-results. Knowledge-of-results or feedback is defined as one of Stolurow's ten critical requirements of a teaching machine.

Stolurow described his conception of knowledge-of-results in a teaching program. If the learner selects the correct alternative among a preprogrammed set of choices, he is told that he was correct and given additional information. If he selects an incorrect alternative, he is told that he is incorrect, the computer provides corrective and supplementary information, and he then makes another choice. This process continues until the correct choice has been made or until the computer provides the correct answer. Feedback implemented by the program in this way is thus sensitive to individual differences in learning. Stolurow claimed that this type of feedback is often preferred over the simple right/wrong feedback when the implementation of the respective functions takes the same amount of time. Otherwise, an immediate right/wrong feedback is preferred. This study examined this claim from a cost-benefit viewpoint, i.e. the corrective feedback function which provides information may be superior to simple right/wrong feedback,
even when the former is more expensive and difficult to implement if this feedback significantly improves student learning.

Geis and Chapman (1971) noted that knowledge-of-results is the most frequently cited reinforcer in the literature on self-instructional systems, especially programmed instruction. They found that most studies are not directly aimed at investigating whether or not answers are reinforcers. The question usually being attached is a broader one. Does feedback in some way affect performance during and after programmed self-instruction?

Geis and Chapman (1971) reviewed the literature in this area and restricted themselves to self-instructional situations. The authors cautioned that research using other than self-instructional materials differ so much from self-instruction that extrapolation is unjustified.

In an investigation of the relationship between test anxiety and feedback in programmed instruction, Campeau (1968) found that feedback was a significant variable in the performance of grade-school girls. Post-instructional test scores were higher for those high-anxiety girls who had feedback during learning. Low-anxiety female students who had no feedback had higher posttest scores than high-anxiety females who had no feedback. No significant
differences were found between low and high anxiety students under feedback conditions. Male students showed no similar regularity.

Cronbach and Snow (1969) reported that this fifth grade study by Campeau used programmed instruction, giving one group feedback to assist in the correction of responses, and the other group no feedback. The number of subjects was small (36 boys, 44 girls) especially since the analysis was performed within sexes. Only persons at the extreme of the anxiety distribution were used, the dependent variable was a posttest score with initial IQ partialled out. For girls there was a significant interaction, with those high on test anxiety doing distinctly better when given feedback and distinctly worse than low anxious when given no feedback. This was also found on a retention test. For boys, the relationships were not significant, and on the immediate posttest there was essentially no effect. Reporting is inadequate. It is uncertain that the low anxious boys are similar to the low anxious girls. It is often found that girls are considerably higher in test anxiety and it may be that a girl's low score matches a boy's high score.

Campeau's (1968) interpretation was that withholding feedback intensifies motivation by maintaining a certain incompleteness. That is to say, the no feedback situation
is more challenging and more stressful. Alternatively, one could perhaps say that the provision of feedback provides greater structure, leaving the person much less on his own resources. The essentially negative result for boys was not explained.

Wittrock and Twelker (1964) found an interesting relationship between knowledge-of-results and rules. While rules alone proved most effective in teaching subjects to decode ciphered sentences, knowledge-of-results was especially useful when rules were not supplied. It did not add to teaching effectiveness when supplied in conjunction with rules, supporting the authors' contention that knowledge-of-results enhances learning, retention and transfer when the information it contains is not greatly redundant.

Geis and Chapman (1971) found conflicting results among studies that examined variable schedules of reinforcement and variable delays in confirmation of correct or incorrect responses. No conclusions were reached about these variables.

Anderson et al. (1972) used several feedback arrangements involving a computer and a program on diagnosing myocardial infarction. In one experiment using several groups, they presented the correct response
(1) only after a correct response had been emitted, or
(2) only after a wrong response had been emitted, or
(3) always (100 percent), or (4) never (0 percent), or
(5) after a correct response, but the subject had to
"loop" back to the same frame after the wrong response.
Criterion test scores were higher for the 100 percent
feedback and the "looped" groups. The only group with
significantly lower test scores was the no feedback
group (0 percent). Of interest here is the fact that no
significant difference was found between the 100 percent
and the "looped" group, although the latter students
underwent much more elaborate feedback procedures. There
was no evidence in this study that knowledge-of-results
functioned as corrective feedback. The group receiving
knowledge-of-results only when errors were made did not
perform significantly better on the criterion test than the
other knowledge-of-results groups. The knowledge-of-
results-only-when-correct group performed at the same level
as the other groups. The function of knowledge-of-results
was not clarified by this experiment. In a recent CAI study,
Keats and Hansen (1972) examined the effects of correctional
feedback on learning. They noted that the precise form and
content for correctional messages that will maximize learning
remains a clouded issue, although the requirement for
correctional feedback to wrong answers in order to facilitate acquisition has been well established. This study compared the effects of using verbal definitions and numerical examples as CAI correctional feedback in a program involving mathematical proofs. Ss were forty-five ninth grade students. Students were only required to state the rule which was applied to each step of the proof. The feedback chosen for a particular step varied according to rules derived by logical analysis carried out by an experienced mathematics instructor. The very low reliability of the instruments prevented conclusions from being drawn about the similarity in posttest and retention scores. However, in terms of errors during the program, providing correctional feedback in the form of a verbal definition was more beneficial to the learner.

Gilman (1967) investigated the effect of various kinds of feedback in a computer assisted instruction (CAI) system. He wrote that "... if there were no purpose to feedback other than to provide the student with reinforcement, statements such as 'you are correct' should prove equally effective as confirmation of a correct answer." University upperclassmen were taught thirty general science concepts by means of a CAI self-instructional system, using a multiple choice format. Various modes of feedback were used: no
feedback, "correct" or "wrong", feedback of correct response, feedback appropriate to the student's response, and a combination of the three latter modes. Students repeated items which were missed until a perfect run through was obtained. The no feedback group and the "correct" or "wrong" group performed less well on the program, making a significantly greater number of responses and requiring a greater number of iterations of the program in order to reach criterion. On the posttest, the combination feedback group scored significantly higher than did the others. This study suggests that more elaborate feedback may be more effective in changing student behaviour.

Hernandez and Gilman (1969) compared the effectiveness of several feedback modes for correcting errors in CAI. Seventy-five university upperclassmen were taught thirty general science concepts. The frames were multiple choice items and five different conditions were administered, from no feedback up to feedback appropriate to the student's response. The results indicated that the most significant factor in rate of error correction is guiding the subject to the correct response. The most significant factor in immediate learning is amount of feedback information the subject receives. The author made an important point by noting that prior studies in programmed learning have not
been able to compare the effectiveness of the several modes of feedback in correcting the student errors because these studies utilized low error rate, linear type programs. Since few incorrect responses are made by a student in this type of learning situation, little is presently known concerning how feedback can be used to correct student errors.

Van Dyke and Newton (1972) examined the effect of immediate and delayed knowledge-of-response in a CAI task. Response differences between the sexes were investigated as well as attitudes toward CAI. Ss were college students taking an Introductory Psychology course. They concluded that short intervals of delay with CAI had no significant effect on the learning or test performance of the individuals used in this study. Delay of knowledge-of-results did result in attitude differences, and this effect varied with the sex of the learner. However, it should be noted that the eleven item achievement test used in the study had a K-R 20 reliability coefficient of .44.

Narva (1970) reported a study with characteristics similar to the present study. He compared two types of CAI programs, one employing branching and the other one linear in format. He also varied the correctional feedback given the student in both types of programs. He used response-sensitive and response-insensitive correctional
feedback in a way similar to the present study except that the response-insensitive feedback provided only the correct answer. He used thirty-two subjects in a 2 x 2 factorial design. The question was raised about whether tailoring the program to individual students is worth the cost. He found that pre-instruction scores were not related to later performance but that aptitude scores were significantly correlated to posttest scores. He also found no significant differences between either the two sequencing programs or between the two types of feedback. However, when an analysis unadjusted for the influence of the aptitude score was performed, a significant difference in favor of response-sensitive feedback was found.

Finer grained analysis of student behaviour and knowledge-of-results begin to reveal specific conditions under which knowledge-of-results seems to be acting as reinforcer. A few studies scattered throughout the literature report on manipulation of subject and test variables and of kinds of feedback. The results of these studies suggest that knowledge-of-results may well be a reinforcer when uncertainty or probability of emitting an incorrect response is high, or where confidence is low.

Geis and Chapman (1971) concluded that the weight of evidence from global studies comparing programs with and
without feedback is that feedback did not enhance learning, as measured by immediate posttest scores or by retention scores. These authors conclude that:

... one might jump into broader questions such as how, when and why information on one's own performance in a learning situation becomes reinforcing and contributes to more effective learning.

Along these lines, several studies have recently concerned themselves with the effect of different types of correctional feedback. These studies were reported above. The present study examines this question as well.

**Summary**

The exact role of correctional feedback on the learning process and product is unclear.

Stolurow (1971), Merrill (1971) and Annett (1969) have made a strong case for the importance of knowledge-of-results in the instructional process.

Some experimenters have shown that correctional feedback has a positive effect on learning and that this effect depends on the nature of the learner. Campeau (1967) provided some evidence for a feedback-by-anxiety interaction on posttest scores, although this study was criticised by Cronbach and Snow (1969). Wittrock and Twelker (1964) showed that knowledge-of-results enhanced learning,
retention and transfer when the information it contained was not redundant. Keats and Hansen (1972) performed a CAI study which provided some evidence that fewer errors were made during learning when correctional feedback in the form of a verbal definition was supplied. Gilman (1967) performed a CAI experiment which suggested that more elaborate feedback might be more effective in changing student behaviour. Hernandez and Gilman (1969) found that the most significant factor in immediate learning was the amount of feedback information the subject received. Narva (1970) carried out a CAI experiment which showed that aptitude scores were related to posttest scores and that response-sensitive feedback was superior to response-insensitive feedback in terms of posttest scores (unadjusted for aptitude).

Despite the conclusion of Geis and Chapman (1971) that feedback did not enhance learning in most studies reviewed, there is enough evidence in favour of correctional feedback to question this conclusion.

If the information content of correctional feedback is important to learning, then differences in performance between the three treatment groups would be expected in this study. It was expected that providing response-sensitive correctional feedback \(T_1\) would provide more
information to the student than providing response-
insensitive correctional feedback (T₂) and that the T₁
treatment condition would then be less difficult than
the T₂ treatment condition. Therefore, it was hypothesized
that in terms of proportion of errors, average latency
and immediate learning, T₁ students would perform
significantly better than T₂ students.

Similar reasoning led to the conclusion that providing
information in the form of response-insensitive correctional
feedback (T₂) will make the lesson less difficult than
providing no correctional feedback other than information
that the student's response was correct (T₃). Therefore,
it was hypothesized that in terms of proportion of errors,
average latency and immediate learning, T₂ students would
perform significantly better than T₃ students.

Higgins (1972) pointed out that feedback appears
to be more effective when the learner possesses a low
level of competence with regard to the instructional task.
If the instructional program is effective, then providing
the student with correctional feedback (T₁ or T₂) would
allow all students to attain the objectives of the unit.
However, if no correctional feedback is provided (T₃), the
lack of information would render the material too difficult
for students who were lacking the prerequisite skills or
who had little mathematical ability. Students who had attained the prerequisites or who were high on mathematical ability would be able to compensate for the lack of information provided and would often be able to provide their own explanation for their incorrect responses. Therefore, it was hypothesized that in terms of proportion of errors, average latency and immediate learning, students who are high on prerequisite skills or mathematical ability would perform better than students low in prerequisite skills or mathematical ability when no correctional feedback is provided (T3).

The critical criterion of success is the product of an instructional session, which in this study was immediate learning. The process variables such as proportion of errors and response latency may be useful for basing decisions during instruction in order to maximize immediate learning. However, a relationship would have to be established between the process and product variables. Therefore, it was hypothesized that there would be a significant linear relationship between the process variables, i.e. proportion of errors and average latency and the product variable, i.e. immediate learning, with the effects of treatment and learner characteristics removed.
Literature on State-Trait Anxiety

Spielberger (1966) pointed out that since 1950 over 1,500 studies indexed under "anxiety" have been reported in Psychological Abstracts. Despite so much effort in the area, attempts to define anxiety have met with difficulties owing to widely different conceptions of anxiety. Szetela (1970) described some of the problems with the anxiety construct. He mentioned differences in definition, limitations of paper and pencil tests, the unidimensional versus multidimensional question, and the state versus trait conceptions of anxiety as unresolved issues.

O'Neil et al. (1969) noted that most studies concerning the effects of anxiety on learning have originated either in artificial laboratory settings or in realistic but poorly controlled natural settings. CAI systems provide a convenient setting in which it is possible to evaluate the learning process under carefully controlled conditions with materials that are relevant to the learner.

O'Neil et al. (1969) observed that research on anxiety and learning has suffered from ambiguity with regard to the status of anxiety as a theoretical concept. Spielberger (1971, 1972) recently emphasized the need to distinguish between anxiety conceptualized as a transitory state or condition of the organism and as a relatively stable
personality trait. State anxiety (A-State) consists of feelings of apprehension and heightened autonomic nervous system activity that vary in intensity and fluctuate over time. Trait anxiety (A-Trait) refers to individual differences in anxiety proneness, that is, to differential tendencies among individuals to respond with different levels of A-State in situations that are perceived as threatening. Persons high in A-Trait are also more disposed to see certain types of situations as more dangerous, particularly situations that involve failure or some threat to that individual's self-esteem. Failure to make this distinction has led to the inappropriate use of operational measures of A-State and A-Trait, and this has contributed to the inconsistent and contradictory findings in investigations of anxiety. The most serious methodological flaws are the use of A-Trait scales to measure transitory anxiety and the common practice of failing to obtain measures of A-State to corroborate the effects of experimental manipulations designed to be stressful (Spielberger, 1972; O'Neil, 1972a).

O'Neil et al. (1969) pointed out that in order to study the effects of anxiety on learning, a theory of learning is needed that specifies the complex relationship between anxiety and behaviour. According to the Drive
Theory proposed by Spence and Taylor (Spielberger, 1972) the performance of high anxious students would be inferior to that of low anxious students on complex or difficult tasks and superior on easy tasks. Much empirical support has been provided for this theory (O'Neil, 1969a, 1972a).

O'Neil et al. (1969) investigated the relationship between A-State and performance on a CAI task for college males with extreme scores on the A-Trait scale of the State-Trait Anxiety Inventory. Difficult and easy CAI learning materials were presented by an IBM 1500 system which also presented the State-Trait Anxiety Inventory (STAI) A-State scale, before, during and after the learning task. The findings of an earlier study (O'Neil et al., 1969) were confirmed in that (a) A-State scores increased while subjects worked on difficult materials and decreased when they responded to easy materials; and (b) high A-State subjects made significantly more errors on the difficult materials than low A-State subjects. While there was no relation between A-Trait and performance, high A-Trait subjects responded throughout the learning task with higher levels of A-State than low A-Trait subjects.

In a later study, O'Neil (1972a) again used a CAI task with college students in an introductory psychology course. Subjects in the stress condition were given negative feedback regarding their performance on a CAI
learning task, whereas subjects in the non-stress condition received neutral feedback. Negative feedback about performance in the stress condition led to greater initial increments in A-State for high A-Trait subjects than for low A-Trait subjects. This did not occur in the non-stress group. These results are consistent with State-Trait Anxiety theory. This study produced different results with regard to the relationship between A-State and errors because the high A-State subjects made significantly more errors than low A-State subjects on the easy materials. This result was not consistent with the prediction from Drive Theory.

One possible explanation of the inconsistent relation between A-State and errors in O'Neil's two studies is that the latter study used only female subjects and the former used males. O'Neil pointed out that the literature suggests that relationship between anxiety and learning is different for men and women. He noted that sex and anxiety interactions probably reflect specific situational variables which influence learning and which may have differential significance for men and women. He suggests that caution must be exercised in making generalizations concerning the relationship between anxiety, sex and learning.

Wine's (1971) review of the test anxiety literature
has indicated that on difficult tasks in which evaluative stress is present, low anxiety (LA) students tend to achieve more than high anxiety (HA) individuals. Wine suggested that HA students, compared to LA, focus a greater proportion of their attention on personal preoccupations and less to task relevant problems.

Tobias (1973) wrote that previous CAI research in which state anxiety was assessed while students were working on instructional programs have indicated higher levels of anxiety for constructing responses compared to reading the program. He examined test anxiety in a CAI study and found no effect on learning and concluded that if anxiety is to exercise debilitating effects, more difficult content than presently used is required. Hensen (1972) found that real reductions in A-State were obtained through increased use of information feedback, although this reduction did not necessarily result in higher levels of performance.

Summary

The findings from anxiety studies have been contradictory for reasons described by Spielberger (1966) and Szetela (1970). Recent work done with the State-Trait Anxiety Inventory (Spielberger et al., 1970) has shown promise in leading to better understanding of the effects
of anxiety on learning. O'Neil (1969, 1972a) has done some CAI research which has produced evidence to support Drive Theory, i.e. that the performance of high anxious students would be inferior to that of low anxious students on complex or difficult tasks and superior on easy tasks. They also found that higher levels of A-State were induced in situations where stress was induced in the students, which meant that the situation was perceived as threatening. Wine (1971) also found evidence to suggest an anxiety by difficulty interaction for stressful tasks.

As discussed in the last section, the three treatment groups in this study should be ranked in terms of difficulty from easy to difficult (T₁ easier than T₂, T₂ easier than T₃). However, it would appear that the large difficulty gap would occur between the T₂ and T₃ groups. The T₁ or T₂ treatments would probably be perceived as relatively easy in comparison to the more difficult T₃ task, where no correctional feedback is provided. The students have had no experience in interacting with a computer and this factor combined with the strange content and surroundings would seem to provide enough stress to induce high levels of anxiety. Therefore, in line with recent evidence it was hypothesized that students who are high in A-State will have a significantly higher proportion of errors and average latency than low A-State students.
when no correctional feedback is provided ($T_3$) and this relationship would be reversed when correctional feedback is provided ($T_2$).

Literature on Aptitude-Treatment Interactions

Bracht (1970) described the goal of research on aptitude-treatment interactions (ATI) as finding significant disordinal interactions between alternative treatments and personological variables, i.e. development of alternative instructional programs so that optimal educational benefits are obtained when students are assigned differently to the alternative programs. The personological variable in ATI research was defined as any measure of individual characteristics, e.g. IQ, scientific interest or anxiety.

Cronbach and Snow (1969) have written a major report in the area of ATI. They defined "aptitude" as any characteristic of the individual that increases (or impairs) his probability of success in a given treatment, and includes personality characteristics. They agreed that the immediate objective of current ATI work is to match specific instructional methods or materials to selected learner characteristics. But more broadly, they argued that ATI research is concerned with theory to overarch diverse ideas such as the branching rules and strategies required in CAI.
As Bracht (1970) pointed out, there is an increasing interest in the topic of ATI among educational researchers, but very little empirical evidence has been provided to support the concept. He conducted a systematic analysis of research studies to investigate the relationship of treatment tasks, personological variables and dependent variables to the occurrence of ATI. He gave a flowchart of a procedure for testing an ATI in a treatment-by-levels factorial design, since most studies used this design with analysis of variance. He suggested that this method is less powerful than regression analysis since creating artificial levels of a continuous personological variable tends to increase the error component in the analysis. Regression analysis, however, was used in relatively few ATI studies.

From his analysis, Bracht (1970) found disordinal interactions in only five of the 103 studies. The results tend to indicate that there is a relationship between disordinal interactions and the degree of control over the treatment tasks of the experiment. Controlled treatment tasks may be a necessary but certainly not a sufficient requirement for disordinal interactions. Measures of specific abilities, interests, personality traits were classified as factorially simple. A personological variable was classified as factorially complex if it was judged to have a substantial loading on many factors in the imaginary
factor matrix, e.g. general ability. Bracht's (1970) results lend some support to the relationship between ATI and the degree of factorial simplicity of the personological variable, although factorial simplicity certainly is not a sufficient requirement for ATI. Many experiments using IQ as a variable found no evidence to suggest that the IQ score and similar measures of general ability are useful variables for differentiating alternative treatments for subjects in a homogeneous age group (Bracht, 1970).

However, Cronbach and Snow (1969) recommended the development of alternative treatments on the basis of general ability. They feel that general ability seems to be nearly synonymous with 'ability to learn', when that term is given its usual common sense interpretation. One treatment should be designed to rely heavily on general ability, and the other treatment should be designed to achieve the same objectives without relying on general ability. This a priori specification of treatments had not been done in past research. The reason for application of a broad, loose construct is that at present there is no evidence to support a more refined one.

Bracht (1970) learned very little from his analysis about the relationship between the dependent variable and the occurrence of ATI because the dependent variable was
most often errors in learning or posttest score. Webb (1972) suggested that ATI studies include as many different criterion measures as possible, e.g. learning tests, retention tests, transfer tests, time to completion, etc. He feels that the current state of the theory of ATI is not well enough developed to determine the specific dependent variables that should or should not be included.

Bracht found that ATI is more likely to occur when two personological variables have been included in the experimental design. One variable is judged to correlate substantially with success in one treatment and the other judged to correlate substantially with success in the second treatment. The correlation between the two personological variables must be moderately low or nonsignificant for the disordinal interaction to occur.

Finally, Bracht suggested that experimenters should begin to formulate hypotheses about ATI with administrative factors, such as cost, in mind. Hence, even ordinal interactions may lead to decisions about differential assignment to treatments when administrative factors are taken into account.

Campeau (1963) found a significant test anxiety by feedback interaction for girls in a study described earlier in the section dealing with literature on knowledge-of-results. O'Neil (1972) found a significant State Anxiety
by task difficulty interaction in another study described earlier in the section dealing with literature on anxiety.

Dick and Latta (1970) compared a programmed instruction version with a comparable CAI version of the same material using grade eight mathematics students. The sixty-four students were randomly assigned to programmed instruction and CAI programs on the topic of significant figures. The results indicated that the students using programmed instruction performed significantly better than those using CAI. This difference was attributed primarily to the very poor performance by the low ability students in the CAI group. There was also a significant ability effect. The posttest and retention test results, as well as number of errors in the actual learning sequence, indicated that there was a trait-by-treatment interaction which was interpreted primarily as a very poor performance by low ability students on CAI, with almost equal performance by high and low ability students utilizing programmed instructional materials. The conjecture may be made that the low ability students are unable to cope with the continuous flow of information as presented by the cathode-ray tube (CRT) without the ability to return to the information previously provided to them.
Becker (1970) wrote that there exists a large number of studies that are indirectly relevant to aptitude-treatment interaction research but that few studies have been designed to investigate interaction between aptitude and instruction. Becker (1970) discussed the idea that various abilities might play an important role in determining what method of instruction is prescribed for a particular learner or group of learners. For example, individuals who are high on mathematical ability should profit more from instruction that provides mathematical mediators than verbal ones. Becker (1970) pointed out some potential difficulties in aptitude-treatment interaction research. He concluded that the selection of aptitude measures that will interact with methods of instruction may be difficult. In general, aptitude measures may be needed that get at specific aspects of mental abilities and with acceptable levels of reliability. Determining the length of the treatment period is another problem. The problem exists of assessing the impact of past instruction on subjects involved in current research. Finally, it is difficult to determine the type of achievement (criterion) measures from which we are likely to derive interactions.
Summary

This brief review of the ATI literature indicates that interactions between aptitude and treatment have been rare and that more work is needed. The evidence from most ATI research is not definitive enough to provide guidance for individualizing instruction.

This study has attempted to provide evidence for the existence of interactions between correctional feedback and anxiety, correctional feedback and prerequisite skills and correctional feedback and mathematical ability.

Literature on Tutorial Computer-Assisted Instruction (CAI)

The most relevant CAI studies have already been reviewed in previous sections of this chapter. Some of the other literature in this area will now be examined.

Stolurow (1968) identified several modes of CAI: problem solving, drill and practice, inquiry, simulation and gaming, tutorial instruction and author mode. This study is concerned with CAI tutorial mode. In this mode, the instructional programmer takes responsibility for the student's instruction on the system. The logic of instruction must be formalized in detail and entered into the system. This mode is in a primitive state of development. It is primarily conceptually rather than empirically based, and its ultimate form will in effect be a theory of teaching.
The theory will depend for development upon specific studies designed to generate data on how to use different rules for instructing students with different response histories and unique characteristics.

Unfortunately, the above theory development has not progressed as well as Stolurow had envisioned. Most discussions of CAI are concerned with computer hardware and software problems. A few are concerned with decision logics and instructional strategies that primarily involve explanation of the functions involved in transferring from instructional block to instructional block. Fewer discussions involve detail about the characteristics of the teaching sequence within these blocks in terms of the stimulus display, the student response or the feedback information required (Glaser, 1971). The interaction of these variables with characteristics of the learner still remains to be studied.

Gentile (1967) and Dick (1965) reached the same conclusion. The matter of personality-computer interaction remains to be studied. One program structure will not be appropriate for all levels of ability and various subject matter areas (Dick, 1965). Gentile (1967) wrote that almost all funds allotted to CAI projects are being spent on the development of courses or equipment to the exclusion of research on teaching and learning variables, where
research is needed most.

Sherman (1971) distinguished two tasks in developing a CAI lesson. The first task is one of designing the pedagogical exchanges, i.e. the sequence of exchanges that conversations may follow. The second task in developing CAI conversations is that of programming the conversational network so that a given computer can play its role in the dialogue. He proposed reducing the time spent on the second task by the use of programmed templates. Sherman (1971) defined the work "template" as:

... a sequence of instructions to the computer for processing a particular network of conversational exchanges and connotes a particular pattern for the presentation of questions, answers and other basic elements of tutorial conversation.

The pattern determines only the logic of the conversational exchanges, not the content of the conversations themselves. Sherman (1971) developed a template and used it to program a dialogue to teach some college physics concepts.

Investigators in several major CAI centres are currently conducting research and development activities in the area of tutorial mode CAI. Several CAI projects were reported by Anderson et al. (1968) at the University of Texas at Austin and Hansen (1971) at Florida State University. In a project at the University of Texas at
Austin (Judd et al., 1970) a CAI course was developed to provide diagnosis of deficiencies in skills prerequisite to freshman science courses. The CAI students achieved well and demonstrated superior performance to the non-CAI students on the posttest. They also found that in some cases program control was superior to learner control and in other cases some form of learner control was superior. Bunderson (1971) felt that the results of this study are so complicated by interactions with pretest score, terminal type, amount of practice and topic as to make generalizations risky. Other CAI programs at Texas are used to teach English, Computer Programming, Business Management, Astronomy Mathematics and Science, Arabic Writing System and Chemistry. The results from these projects are not conclusive. The projects are regarded as exploratory in nature and provide information and methods to ease the problem of designing high quality instructional programs; the costs of preparation, maintenance, and revision are the primary variables. Minimum levels of student performance, time to complete and attitude ratings are used as design criteria.

Several recent studies have utilized tutorial mode CAI to study the instructional process. Some of these studies (Gilman, 1967; Keats and Hansen, 1972; Van Dyke, 1972) have been described in the earlier sections of this chapter. Other studies in the area are described below.
Sutter and Reid (1969) showed that the effectiveness of CAI in teaching a course in problem solving is the same for the student working alone with the machine as for the student working with a partner at the machine, except when conditional upon certain personality traits. College students were used and high test anxiety was associated with negative attitudes toward CAI in both the paired and alone groups. A significant interaction was obtained between test anxiety and achievement for the two groups. Students high in test anxiety achieved better working alone, while those low in test anxiety achieved better working with a partner. An interaction was also found between sociability and achievement for the two groups.

Bunderson and his colleagues (Bunderson, 1971) developed an imaginary science task called a Xenograde system. The Xenograde system has the hierarchical structure of concepts and quantitative rules characteristic of many topics in science education. The greatest advantage of its imaginary character has been to enable researchers to concentrate on design variables - structure, display, etc. rather than subject matter variables. Several CAI studies of learning have been conducted with this topic.

Olivier (1971) compared the performance of students in the learner control mode with students for whom the sequence was controlled by the program. He matched students in both
groups and so the data were not treated statistically but are suggestive only. The conclusion is that except for a small number of exceptional students, learner control of the sequence of lessons in a hierarchy may be less effective for learning new material than a rationally planned, carefully designed program-controlled sequence. Bunderson (1971) wrote that in subsequent studies using partially familiar material the results were less clear cut.

Merrill (1971) investigated the effects that availability of behaviourally stated objectives would have on the learning process. The Xenograde science was used with 130 college students. The results showed that objectives significantly reduced the number of examples required to learn the task. Objectives did not reduce total latency but did reduce test-item response latency. No significant differences were found between treatments on the posttests or retention tests, but a significant rule effect was found in favour of the groups which received the rule as opposed to examples. Significant ability-by-treatment interactions were obtained using test-item-response latency as criterion and reasoning factor scores, plus individual reasoning tests as covariables. On the basis of the results of this study it was concluded that objectives have orienting and organizing effects which dispose students
to attend to, process and structure relevant information in accordance with the given objectives.

Lorber (1970) demonstrated that CAI is an effective means by which to teach the basic elements of tests and measurements and pupil evaluation of prospective secondary school teachers. His results showed that the CAI group scored higher on the posttest than the conventional classroom group and needed less instructional time. Attitudes towards CAI were favourable.

Tira (1970) produced a CAI program dealing with the Product-Moment facility of correlations. This non-experimental study had four phases: (1) definition of requirements, (2) design of lesson content, (3) production of CAI dialogue from content, (4) evaluation of the program. The program was judged to be successful and the author recommended that the entering characteristics of the learner be identified and paired with a program sequence which would best facilitate the meaningful learning of the concepts on the CAI course.

Ibrahim (1970) compared CAI with other instructional methods in the teaching of the concepts of limits in freshman calculus. The other instructional methods were (1) the instructor centred or traditional approach and (2) a combination of traditional and CAI. The findings
were that the CAI students did significantly better than traditionally taught students on immediate achievement but no significant differences were found in retention, attitudes toward CAI and toward mathematics. CAI was as effective as other methods in teaching the concepts of limits.

Castleberry (1970) developed and evaluated CAI programs on selected topics in introductory college chemistry. These topics were a combination of tutorial drill and simulation modules designed solely as supplementary study aids. The conclusions were that the students acquired the behavioural objectives of the modules to varying degrees. The modules allowed for a range of individual differences based on ability, prior learnings and self-evaluation. The CAI programs had a significant effect on achievement as measured by the final examination. Full scale implementation of a course with these modules would be feasible.

Cropley and Gross (1970) compared a group of university students who received instruction in FORTRAN programming via CAI through a remote terminal connected to a computer more than 400 miles away with a programmed instruction group and a conventional lecture group. All three methods proved to be equally effective and no serious
negative feelings about being taught by machines were reported by the students. CAI compared favourably with traditional instruction as far as time was concerned. Their findings suggest that CAI is a realistic and acceptable alternative to traditional classroom procedures in appropriate situations.

Oldehoeft and Conte (1971) developed a computer system at Purdue University to teach portions of an undergraduate course in numerical methods. Each instructional unit or lesson was divided into three modes of instruction which allowed the student to progress from a computer-controlled presentation to a student-controlled investigation. These were tutorial mode, problem mode and investigation mode.

The system was designed as a classroom independent course of study, and had been used for two semesters by students in place of conventional classroom instruction. The program consisted of twenty-five lessons. The tutorial mode was similar to linear programmed instruction where the student responded to a mixture of multiple choice and constructed response type items. The instructional strategy here was similar to that developed by Bork (1971). A major factor which limits the overall effectiveness is a general lack of anticipated incorrect responses built into the program. The overall indication was that the average CAI student performed
as well as he would have under the conventional system. The overall attitude toward CAI was favourable.

Fenichel et al. (1970) developed the TEACH system at MIT to ease the cost and improve the results of elementary instruction in programming. To the student, TEACH offers loosely guided experience with a conversational language which was designed with teaching in mind. Faculty involvement is minimal. The evaluation of the project indicated that the technical aim of completing the system and bringing it into production and smooth operation has been met. No tests have been made to determine the efficacy of the teaching method, although interviews with the students determined that the students had in fact learned the material. The authors distinguished between semantic and syntactic errors. The technical issue of error detection was raised and the authors described the problem of semantic error detection as that of informing a student of what error he has made and offering him suitable help at the appropriate time. The system must be able to go beyond superficially erroneous input to determine whether it was a simple slip or whether it was the result of some deep conceptual misunderstanding. This task is presently being tackled by the experimenters.

Bork and Sherman (1971) and later Kalman, Kaufman and
Ladd (1971) used a tutorial program to teach the proof of the conservation of energy to college students. The CAI lesson proved successful, actively involving the students in a tutorial lesson and teaching the concepts involved. Several problems were noted. The difficulty of using standard Calculus notation on a computer terminal and the inability of the computer to recognize all correct and incorrect responses were notable limitations.

Hansen (1966) reviewed CAI tutorial applications and found that the most consistent finding is the marked saving in instructional time with no loss in post-instruction achievement test performance.

Kromhout, Edwards and Schwartz (1969) described the use of computers in physics instruction. They presented a description of representative CAI projects in physics and concluded that most projects were still in the early testing stage. They also concluded that the varied and imaginative uses of the computer were encouraging and that introduction of the computer into physics instruction represented a significant development.

Atkinson (1968) described a CAI tutorial project to teach reading to first grade culturally disadvantaged children. An experiment was conducted which compared a CAI group to a traditional group taught by a teacher in the
classroom. The two groups were not significantly different at the start of the year, but at the end of the year the group that received computer-assisted reading instruction performed significantly better on almost all of the reading achievement tests. He concluded that from the standpoint of both the rate of progress and the total number of problems completed during the year, the computer curriculum appeared to be quite responsive to individual differences. Few sex differences were found and the results suggest that with CAI, sex difference is minimized as the emphasis moves toward analysis and away from rote memorization. The one kind of problem on which the girls achieved significantly higher scores than the boys, word-test learning, is essentially a memorization task. Students, teachers and parents reacted favourably to the introduction of CAI to the classroom. Various optimization routines were evaluated and Atkinson believes that these evaluations have suggested other experiments and analysis which could lay the groundwork for a theory of instruction truly useful to the educator.

Cartwright and Mitzel (1971) developed a mobile CAI laboratory at Pennsylvania State University utilizing an IBM 1500 instructional system. A CAI course was developed which would provide intensive training in special education
concepts to sparsely populated counties. The course was called Computer-Assisted Remedial Education (CARE). Pilot groups and other formative evaluation procedures were used to produce a CAI course which was internally valid and error free. Summative evaluations have shown that students who took the CAI course scored significantly higher in achievement and used about one-third less time to cover the same objectives than students instructed in the conventional lecture-discussion method.

Lower (1971) recently reported on CAI activities at Simon Fraser University (SFU) in British Columbia. He reported that more than eighty CAI courses have been authored at SFU but that most of these have been experimental or exploratory in nature. Only about ten have actually received substantial use in connection with regular university or high school courses. Most of the courses are in chemistry, but there has been some authoring activity within the areas of physics, mathematics, biology and economics, while the high school courses cover a wider sphere. He notes that students have played an important role in programming of the courses. An important conclusion is the idea that CAI is only one component of an instructional system and that computer managed instruction may be more effective in practice.
The most sophisticated and advanced CAI system is currently the PLATO system at the University of Illinois (Bitzer, 1967; Braunfield et al., 1962; Alpert et al., 1970). Hammond (1972) wrote that the PLATO system is one of the most ambitious time sharing systems ever attempted. Much of the hardware, a new programming language adapted for teaching, and economical new techniques for linking remote terminals to a central computer were designed specifically for educational use. The student terminals are perhaps the most sophisticated and expensive devices ever developed for communicating with a computer. For authoring new courses, a programming language (Tutor) based on English grammar and syntax is designed for use by teachers with no knowledge of computers. Some 200 such teachers of varying backgrounds have created courses with Tutor and earlier versions of PLATO. Bitzer et al. (1967) described the application of the PLATO system to science education. Lessons on genetics, chemistry, physics, engineering and elementary school topics are being used.

Braunfield and Fosdick (1962) pointed out that the power of the computer based teaching system stems from its ability to pose complex questions, judge the students' answers to these questions and take an appropriate course of action on the basis of student responses. The computer also
keeps detailed and accurate records of student performance, which are useful guides to improving course content. The authors reported a study using PLATO to teach nine undergraduate students a portion of a course in computer programming. The teaching logic was defined and the authors presented tables to indicate the most useful types of data which can be gathered about the instructional process. They concluded that the students found the PLATO system very easy to use and that the system did not distract the students' attention from the lessons themselves.

Alpert and Bitzer (1970) reported on the PLATO IV system, which is the latest version of this system. They reported a study in which a class of twenty students in a medical science course was taught for a semester entirely with the PLATO IV system. When compared with a control group in a nationally administered test, the students taught with the PLATO IV system were found to have scored as well in grade performance even though they had required only one-third to one-half as many student contact hours of instruction as those taught in the conventional classroom. Subsequent measurements extending over a twenty-six week period indicated that the PLATO group showed a greater retention over that interval.
Bitzer et al. (1967) claimed that CAI was effective in teaching electrical engineering. Students taught by the inquiry method showed greater problem solving ability than those taught by the tutorial method. He further claimed to have gained some insight into the learning process, thereby improving the material presented in both inquiry and tutorial modes. He concluded that the PLATO-CAI system can both teach and explore physical and behavioural experiments, thus he described his system as versatile and flexible.

Summary

The purpose of this review of tutorial CAI was to provide a variety of examples which would demonstrate the potential contribution of CAI to education. The studies relevant to the present study were discussed in earlier sections of the chapter. A wide range of activity is ongoing in the area of tutorial CAI with regard to hardware (Hammond, 1972), software (Fenichel et al., 1970), instructional courses (Bitzer et al., 1967; Cartwright and Metzel, 1971; Lower, 1971), instructional strategies (Bork, 1971; Oldehoeft and Conte, 1971).

Summary of Research Hypotheses

The research questions of interest were raised in
Chapter 1. The questions can be translated into specific hypotheses as follows:

la. In terms of proportion of errors, average latency and immediate learning, students provided with response-sensitive correctional feedback ($T_1$) will perform significantly better than students provided with response-insensitive correctional feedback ($T_2$).

lb. In terms of proportion of errors, average latency and immediate learning, students provided with response-insensitive correctional feedback ($T_2$) will perform significantly better than students provided with no correctional feedback ($T_3$).

2. Students who are high in A-State will have a significantly higher proportion of errors and average latency than low A-State students when no correctional feedback is provided ($T_3$) and this relationship will be reversed when correctional feedback is provided ($T_2$).

3. In terms of proportion of errors, average latency and immediate learning, students who are high in prerequisite skills will perform better than students low in prerequisite skills when no correctional feedback is provided ($T_3$).
4. In terms of proportion of errors, average latency and immediate learning, students who are high in mathematical ability will perform better than students low in mathematical ability when no correctional feedback is provided ($T_3$).

5. There will be a significant linear relationship between the process variables (proportion of errors and average latency) and the product variable (immediate learning) with the effects of treatment and learner characteristics (A-State, prerequisite skills, mathematical ability) removed.
CHAPTER III

METHOD

Subjects

The experimental subjects consisted of sixty-three preservice elementary school teachers in the Faculty of Education at the University of British Columbia. These students were following a compulsory course in methods of teaching mathematics and they were awarded credit towards their final course grade for participating in the experiment.

A pilot study carried out in the developmental stage of the materials suggested that the content is most suitable for undergraduate students having some mathematical or scientific background (Kalman, Kaufman and Smith, 1972). Students from the Faculty of Education were utilized in this study since these students had studied the necessary secondary-school mathematics, but would probably find the material fairly difficult. It was assumed that these students would make more errors during learning. These incorrect responses would provide data for evaluation of the effects of correctional feedback on student performance and would provide a valid test of the program's teaching effectiveness.
Experimental Procedures

The experimental procedure was divided into one day periods: (1) initial lecture and testing session; (2) task period on CAI computer terminal followed by posttest and debriefing.

The procedure is listed below in Table 1.

<table>
<thead>
<tr>
<th>DAY 1</th>
<th>Activity</th>
<th>Variables Measured</th>
<th>Approximate Time Required (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Short lecture given to subjects.</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>2.</td>
<td>Tests administered to subjects.</td>
<td>State and trait anxiety, mathematical ability.</td>
<td>80</td>
</tr>
<tr>
<td>DAY 2</td>
<td>3. CAI prelesson taken by subjects.</td>
<td>Errors, latencies, overall score, state anxiety.</td>
<td>30</td>
</tr>
<tr>
<td>4.</td>
<td>CAI main lesson taken by subjects.</td>
<td>Errors, latencies, state anxiety.</td>
<td>90</td>
</tr>
<tr>
<td>5.</td>
<td>Posttest administered to subjects.</td>
<td>Immediate learning.</td>
<td>35</td>
</tr>
<tr>
<td>6.</td>
<td>Short debriefing given to subjects.</td>
<td>-</td>
<td>5</td>
</tr>
</tbody>
</table>
The experimental subjects were tested in three separate groups during DAY 1 except for six students who arranged to write the tests at separate times. The DAY 1 testing sessions were also utilized to schedule students for the DAY 2 computer sessions.

The DAY 2 sessions were held Monday to Friday at 9:00 a.m. and 5:00 p.m. for most students, although sixteen students completed these sessions on either Saturday or Sunday morning or afternoon. The experimental subjects defined earlier were run in groups of three to five persons on IBM 2741 computer terminals in an isolated room above the Computing Centre at the University of British Columbia. Subjects from each of the three treatment groups worked simultaneously in order to control for extraneous environmental and time variables. The CAI sessions were interrupted only once when the computer became inoperational for fifteen minutes near the start of the prelesson. Four students were required to restart their CAI lessons and to re-enter their responses up to the point of the interruption. A few minor difficulties were encountered with the terminals but these were easily remedied by replacing the type-ball or by transferring the student to another terminal.

Design

The subjects were randomly assigned to three treatment
groups and a balanced design was obtained with twenty-one students in each group.

Each group received the same content and instructional logic for the CAI lesson. The three treatment groups differed in terms of the instructional strategy employed to achieve the main lesson instructional objectives. The difference was specifically in terms of the different type of correctional feedback provided to the learner.

All three treatment groups received identical information regarding the correct response together with the explanation at some point during the implementation of the particular instructional strategy. The key independent variable in the experiment was correctional feedback and it was the informational content of the feedback that was being varied.

The other independent variables represented both cognitive and personality characteristics of the students.

The cognitive variables differed in terms of their relationship of the specific CAI task. These were mathematical ability and ability to perform on the prelesson. Cronbach and Snow (1969) have suggested that the pretest score is an aptitude and should be treated along with other aptitudes.

The personality variables were both trait- and state-
anxiety. State-anxiety was measured at three points throughout the experiment and Trait-anxiety was measured at the beginning.

The dependent or criterion variables in this study were posttest score, proportion of errors during learning and average response latency. The latter two were the process variables and the former was the product variable. Suppes (1967) claimed that response latencies are more sensitive measures of skill mastery and depth of learning than the response errors themselves and response latencies were examined as well.

Unanticipated student responses and the number of times the student asked for help were recorded for post hoc analysis, as well as means and correlations of selected experimental variables.

Instructional Logic for Prelesson

The template used in the prelesson is shown in Figure 2. The flowchart reveals how this CAI tutorial lesson served as a pretest of prerequisites. A student was first tested on the prerequisite concept and then given instruction in that concept only if he failed initially to respond correctly. After the concept was taught, the student was again tested, but on a different example. As
Question is asked

Can student answer on first try?

yes *Mark = 2

no Assistance is given to student

Student is asked to answer once again

$Q_i$ Question is asked similar to above

Mark = 0 no Can student answer on first try?

yes Mark = 1

$Q_{i+1}$

$Q_{i+1}$ Next question is asked

* Mark refers to the grade assigned to the student for a particular instructional unit, or item, $Q_i$.

Figure 2

Prelesson Instructional Logic
Figure 3
Main Lesson Instructional Logic

* $Q_i, Q_j, Q_k, Q_m, Q_{i+1}$, all represent different instructional units (IU) in the lesson.

$\geq$ means the $n^{th}$ time through the block.
shown in the flowchart, a student received a mark of 0, 1, or 2 on each instructional unit, based on his previous knowledge and his ability to learn the concepts new to him.

The prelesson had three functions:
(a) to provide a measure of the student's knowledge or ability to learn this particular domain of content in this particular medium;
(b) to ensure that the student had attained the necessary prerequisites before proceeding to the main lesson; and (c) to provide practice in working on the CAI terminal.

Instructional Logic for Main Lesson

A flowchart of the instructional logic used for the three treatment groups on each instructional unit is shown in Figure 3. An explanation of the flowchart logic will now be given. The student is first asked a question by the computer and he responds either by asking for help or by attempting to answer the question. If he types HELP, a hint is given and he must respond again. If he types HELP a second time, the student is given the correct answer with an explanation before proceeding to the next instructional unit.

The student who responds to the original question may respond correctly. In other words, his answer matches a predetermined correct answer keyword. When this match occurs, the computer types an appropriate encouraging comment
such as "good". The wording of the comment depends on the value of a counter, GX, which keeps track of the number of consecutive correct replies up to four in a row. After the encouraging comment, the computer provides the correct answer with an explanation before proceeding to the following instructional unit.

The student may respond incorrectly to the original question. This means that his answer matches a predetermined incorrect answer keyword. The computer may branch to another question for remedial assistance or may provide correctional feedback, depending upon the prior decision of the instructional programmer. Making two incorrect responses of the same type, that is, falling into the same wrong answer class twice, causes the correct answer and an explanation to be provided before proceeding to the following instructional unit. An incorrect response re-initializes the counter, GX, to zero.

The student's response may not match any of the correct or incorrect keywords and his response will not be recognized by the computer. One or two NOMATCH responses cause a comment to be provided and the student is asked to try again. A third NOMATCH response causes the computer to provide the student with the correct answer and an explanation before proceeding with the subsequent
instructional unit.

The option also exists for branching to other instructional units if a correct or a particular incorrect response is recognized.

Operational Definitions of Treatments

The first treatment group ($T_1$) was instructed precisely according to the instructional logic shown in Figure 3. The deepest level of interaction was attained between the learner and the computer through the instructional program because the nature of the student's incorrect response was used as the criterion for providing response-sensitive correctional feedback. This feedback was determined by prior analysis of each question by the instructional designer.

The second treatment group ($T_2$) received response-insensitive correctional feedback. Each $T_2$ subject was provided with a hint when he responded incorrectly. This hint was predetermined and was provided to each $T_2$ subject regardless of the nature of his incorrect response. An important criterion for choosing the hint in $T_2$ was that no more information would be provided than could be obtained from all the hints for the corresponding instructional unit in $T_1$. The comment blocks which followed the wrong answers
all contained identical comments for a particular instructional unit (see Figure 3).

The third treatment group (T3) received no correctional feedback information. Each T3 subject was merely informed about the incorrectness of his response and no remedial information was provided. The comment blocks which followed the wrong answers contained no hints, but contained only information telling the T3 subject that his answer was incorrect.

The reader can refer to Appendix D in order to compare the three versions of the main lesson, T1, T2 and T3.

**CAI Author Language**

The CAI author, or programming, language was written by the experimenter in FORTRAN IV and requires a minimum amount of computer knowledge and experience on the part of a user.

A User's Guide for the language along with a source listing of the program is provided in Appendix A. This language was modified in order to implement the instructional logic for the prelesson. These modifications are described and a listing of the modified source program is provided in Appendix B.

**Instructional Materials**

The procedure used in designing the instructional
materials was described in a review of modular instruction by Goldschmid and Goldschmid (1971). The procedure consisted of the following steps:

1. Identification of the subject matter to be taught
2. Definition of a set of objectives
3. Deciding upon the hierarchy of objectives which in turn describes the sequence of instruction
4. Identification of prerequisites
5. Development of a pretest
6. Provision of instructional options
7. Design of a posttest

The subject matter consisted of the concept of the derivative in elementary calculus and the relationships between the mathematical concepts and the physical concepts of distance, speed and time. The lesson could be characterized as a mathematical derivation supplemented by numerical problems which are solved during the lesson. This topic was chosen to satisfy the requirement for a module to teach this material to a group of undergraduate science students at Loyola College in Montreal, Quebec (Kalman, Kaufman, Smith, 1972). The CAI module is currently fulfilling this role but in a different form than the one used in this experiment. Cronbach and Snow (1969) have suggested that the ideal treatment-set for ATI research is
likely to consist in applications of some regular instructional material. This suggestion was followed in this study.

The prerequisites for the main lesson are given in Table 2. These were identified by a logical analysis of the content area performed by the investigator with the assistance of two college instructors who had been teaching mathematics and science courses for at least three years (Kalman, Kaufman, Smith, 1972). The prerequisites were subsequently modified after a pilot test of the program.

The prelesson dealt with these prerequisites. An overview of the content of the prelesson is given in Table 2 and a detailed view of the prelesson is shown in Figure 4. If a subject had acquired the prerequisite objective, he proceeded immediately to the following item. If not, he was instructed and later retested on this prerequisite, as indicated earlier in Figure 2. A detailed listing of the CAI prelesson is given in Appendix C with the accompanying graphs.
Reading a graph

Evaluating the value of a function at a point

Using distance = speed x time to find distance given speed and time

Using DEL(S) notation to find change

Calculating average speed given distance and time

Knowledge of the meaning of the term "instantaneous speed"

Five item A-State instrument is given

Calculating the slope of a straight line graph

Reducing an algebraic expression such as \[
\frac{(2+x)^2-2^2}{(2+x)-2}
\]

Reducing same algebraic expression as above but using DEL(S) in place of x

Signoff

Figure 4

Detailed View of Prelesson
TABLE 2

PREREQUISITES FOR MAIN LESSON

1. Ability to read a graph, i.e. to find a value at a point.

2. Ability to calculate the value of a function at a point, given the equation.

3. Knowledge of the terms "average speed" and "instantaneous speed".

4. Ability to calculate distance when given speed and time, using the formula, distance = (speed) (time).

5. Knowledge of the concept of change in distance or time.

6. Ability to apply the notation, DEL(S) and DEL(T) to calculate change.

7. Knowledge of the definition of "slope".

8. Ability to calculate the slope of a straight line.

9. Ability to expand a binomial which is squared and to factor, i.e. ability to reduce algebraic expressions such as \( \frac{(2 + x)^2 - 2^2}{2 + x - 2} \) to simplest form.

10. Ability to perform the above algebraic manipulations using the cumbersome notation used on a computer terminal, e.g. \( (2 + \text{DEL}(S)) \times 2 - 2 \times 2 / (2 + \text{DEL}(S)) - 2 \).

The objectives for the main lesson were determined and these provided the rationale for the logic of the main lesson content. These instructional objectives are given in Table 3 and a detailed view of the content of the main lesson is given in Figure 5. Detailed listings of the main
lesson, versions $T_1$, $T_2$ and $T_3$ are provided in Appendix E. The fifteen instructional units analyzed in the study are the instructional units with the following number in Appendix E: 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 23, 24. These units were the ones given to all students in the experiment. Units 15, 16 and 17 comprised the optional section on limits. Units 18 to 22 comprised the A-State scale and Unit 10 was an exposition of some content followed by the question, "Do you understand?"

A posttest was developed and is given in Appendix F. The items of the test reflected the specific behaviours implied by the instructional objectives.
TABLE 3

INSTRUCTIONAL OBJECTIVES FOR MAIN LESSON

1. Recall the relationship between the following:
   (a) slope of secant and average speed
   (b) slope of tangent and instantaneous speed
       (at a point)
   (c) average speed and instantaneous speed
   (d) slope of tangent and derivative (at a point)

2. Calculate average speed from a graph of distance vs. time for both linear and non-linear graph.

3. Calculate instantaneous speed from a graph of distance vs. time with tangent to the curve drawn at a point on the graph.

4. Calculate simple limits, e.g. \( \lim_{\Delta t \to 0} (6 + 3\Delta t) \)

5. Define instantaneous speed at any time \( t \) as a function of \( s \) and \( t \), i.e. \( v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} \)

6. Calculate average speed and instantaneous speed at a point, given the equation of \( s \) as a function of \( t \). The student must use basic principles, i.e. limit definition.

7. Calculate the derivative \( (dy/dx) \) at a point given the equation of \( y = f(x) \), from basic principles, i.e. limit definition.
Relationship between slope and average speed of straight line graph of S vs. T. Shown to be constant

Relationship between slope of secant and average speed for non-linear graph of S vs. T. Not constant

Relationship between slope of tangent and instantaneous speed at a point

Relationship between average speed and instantaneous speed, i.e., instantaneous speed is limit of average speed

Examples of finding instantaneous speed given non-linear graph of S vs. T with tangent drawn on it. Can student do it?

Notation and definition of derivative are given

Example of computing average speed from equation of S vs. T at a point

Finding instantaneous speed by taking limit of average speed. Can he do it?

Evaluating limits

A-State instrument - five items

Another example of computing instantaneous speed from equation of S vs. T. Can he do it?

Signoff

Figure 5
Detailed View of Main Lesson
Measurement Instruments

The analysis of all measurement instruments was performed using the PIA and TIA test analysis programs available in the Faculty of Education at the University of British Columbia.

Posttest. The eighteen-item multiple choice posttest was designed to measure student performance on the objectives given in Table 2. This instrument was intended to serve as a criterion-referenced test and a copy is given in Appendix F.

Content validity was assured for this test by generating specific items from the list of instructional objectives with due regard given to the relative emphasis given to these objectives in the main lesson. Test analysis data for this instrument is given in Tables 4 and 5.

TABLE 4

POSTTEST DATA

<table>
<thead>
<tr>
<th>Sample size</th>
<th>63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.95</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.89</td>
</tr>
</tbody>
</table>
TABLE 5

ITEM ANALYSIS INFORMATION FOR POSTTEST

<table>
<thead>
<tr>
<th>Item</th>
<th>Proportion Answering Correctly (Difficulty)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pooled</td>
</tr>
<tr>
<td>1</td>
<td>.54</td>
</tr>
<tr>
<td>2</td>
<td>.44</td>
</tr>
<tr>
<td>3</td>
<td>.78</td>
</tr>
<tr>
<td>4*</td>
<td>.71</td>
</tr>
<tr>
<td>5</td>
<td>.94</td>
</tr>
<tr>
<td>6</td>
<td>.40</td>
</tr>
<tr>
<td>7</td>
<td>.49</td>
</tr>
<tr>
<td>8</td>
<td>.40</td>
</tr>
<tr>
<td>9</td>
<td>.84</td>
</tr>
<tr>
<td>10</td>
<td>.78</td>
</tr>
<tr>
<td>11</td>
<td>.51</td>
</tr>
<tr>
<td>12</td>
<td>.68</td>
</tr>
<tr>
<td>13</td>
<td>.19</td>
</tr>
<tr>
<td>14</td>
<td>.33</td>
</tr>
<tr>
<td>15</td>
<td>.16</td>
</tr>
<tr>
<td>16</td>
<td>.43</td>
</tr>
<tr>
<td>17</td>
<td>.08</td>
</tr>
<tr>
<td>18</td>
<td>.25</td>
</tr>
</tbody>
</table>

*The seventeen subjects who answered this item before a typographical error was corrected on the posttest were assigned a value of "1" for the purpose of using the item analysis program.

The results shown in Table 5 indicate that there were no meaningful differences between the three groups on the individual items, but that certain items were too difficult and should be revised. The difficult items were 13, 15, 17 and 18.
Mathematical ability test. The Cooperative Sequential Test of Educational Progress, Mathematics Form 2A (1957), was administered to all subjects at the beginning of the experiment. The norm sample for this form of the test consisted of students in grades ten, eleven and twelve and the test was found to be of appropriate difficulty level for students participating in this experiment.

The internal consistency coefficient, K-R 20, for this form of the test normed on grade eleven students was reported to be .84. The concurrent validity coefficient was defined as the correlation with the SCAT-Quantitative test and was reported as .70 for a grade eleven sample and .76 for a grade twelve sample.

The test consisted of fifty items and was administered in seventy minutes. For the total sample of sixty-three students, the mean was 31.1, the standard deviation was 7.6 and the coefficient of internal consistency, K-R 20, was .85.

A logical analysis of the test items seems to suggest that higher-order mental processes, such as problem solving, were being measured and not only recall of information or application of algorithms. The latter two processes were emphasized in the prelesson.
State-Trait anxiety inventory. The State-Trait Anxiety Inventory (STAI) was utilized in order to measure both A-State and A-Trait (Spielberger et al., 1970). The twenty-item A-State and A-Trait four point Likert scales were administered at the beginning of the experiment. In addition, a short form of the A-State scale (O'Neil, 1972), consisting of the five items with the highest item-remainder correlations in the STAI normative sample were given during the prelesson and during the main lesson. These five items were administered by the computer during the CAI lesson.

The twenty-item A-State and A-Trait scales have been shown to have high value of reliability, i.e. Cronbach's alpha, and evidence of construct validity has been provided (Spielberger et al., 1970). O'Neil (1972) reported reliability (alpha) coefficients for the five-item scale ranging from .83 to .93 in seventeen administrations.

The test statistics for this study are reported in Table 6.
TABLE 6

ANXIETY TEST DATA

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean</th>
<th>S.D.</th>
<th>Cronbach Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Trait (20 items)</td>
<td>41.9</td>
<td>8.5</td>
<td>.88</td>
</tr>
<tr>
<td>A-State (20 items)</td>
<td>39.1</td>
<td>9.4</td>
<td>.89</td>
</tr>
<tr>
<td>A-State pretest (5 items)</td>
<td>9.6</td>
<td>3.8</td>
<td>.92</td>
</tr>
<tr>
<td>A-State main (5 items)</td>
<td>12.0</td>
<td>4.5</td>
<td>.92</td>
</tr>
</tbody>
</table>

Prelesson. The grading scheme used for the prelesson was discussed earlier. A student received a grade of 0, 1, or 2 on a single instructional unit and there were nine instructional units in the lesson.

The prelesson was considered as a test of a student's knowledge and ability to learn the prerequisites required for the main lesson as taught by the computer. The prelesson data are given in Tables 7 and 8.

TABLE 7

PRELEsson DATA

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>14.4</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.84</td>
</tr>
</tbody>
</table>
TABLE 8

ITEM ANALYSIS INFORMATION FOR PRELESSON

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>*r&lt;sub&gt;total&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.73</td>
<td>.48</td>
<td>.35</td>
</tr>
<tr>
<td>2</td>
<td>1.78</td>
<td>.42</td>
<td>.32</td>
</tr>
<tr>
<td>3</td>
<td>1.92</td>
<td>.27</td>
<td>.52</td>
</tr>
<tr>
<td>4</td>
<td>1.90</td>
<td>.29</td>
<td>.17</td>
</tr>
<tr>
<td>5</td>
<td>1.87</td>
<td>.38</td>
<td>.22</td>
</tr>
<tr>
<td>6</td>
<td>1.92</td>
<td>.27</td>
<td>.29</td>
</tr>
<tr>
<td>7</td>
<td>1.73</td>
<td>.44</td>
<td>.34</td>
</tr>
<tr>
<td>8</td>
<td>0.68</td>
<td>.64</td>
<td>.73</td>
</tr>
<tr>
<td>9</td>
<td>0.90</td>
<td>.81</td>
<td>.71</td>
</tr>
</tbody>
</table>

*<sup>r</sup><sub>total</sub> represents the correlation coefficient of that item with the total test score.

Table 7 indicates that the prelesson was not difficult for this group since the mean score for the total group was 14.4 on a possible score of 18. The last two items were the only ones which the students found difficult.

Main lesson. The main lesson was considered as a measure of a student's ability to perform on a CAI terminal. The student's errors and latencies were recorded for subsequent analysis.

Each instructional unit was also considered as a test item with possible scores of 0 or 1. The student was
assigned a value of 0 for an item if the computer provided the correct answer before he answered correctly. If the student answered correctly before being given the answer, he was assigned a grade of 1 for that item.

Analysis information for the main lesson regarded as a test is given below in Table 9.

**TABLE 9**

**MAIN LESSON DATA**

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Items</td>
<td>15</td>
</tr>
<tr>
<td>Mean</td>
<td>10.9</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 9 indicates that the mean score for the group was 10.9 out of a possible 15. This finding shows that most students were able to produce the correct answer before the computer did so, and the lesson was a relatively effective instructor.
CHAPTER IV

ANALYSIS AND RESULTS

Method of Analysis

In this study two phases were involved in the analysis of data. The first phase consisted of a regression analysis procedure designed to test the research hypotheses stated in Chapter II. The second phase involved some post hoc analysis of the data in order to gain additional insight into the results of the first phase as well as to examine several alternative questions. This second phase involved the examination of intercorrelations for a variety of measures, which were examined for the total group as well as separately for the three experimental groups. Graphs of latencies and errors for the main lesson were also examined for meaningful information.

The regression analysis approach employed for this analysis has been described by many writers (Bottenberg and Ward, 1963; Cohen, 1968; Overall and Spiegel, 1970; Walberg, 1971; Kaufman and Sweet, 1973). The advantages of this method of data analysis over the conventional ANOVA approach have been discussed in detail by these writers.
Cronbach and Snow (1969) recommended the use of the regression analysis method for testing interaction terms in ATI studies. Separate stepwise univariate regression analyses were performed for each of the three criterion variables in order to test the first four hypotheses in this study.

Hypothesis 5 was tested using a regression analysis approach with posttest score as the dependent variable. The proportion of errors, average latency and learner characteristics defined earlier served as independent variables. This analysis technique permitted the learner variables and treatment effects to be statistically removed (partialled) in order to test the relationships between posttest score and the other two variables.

All analyses were performed at the University of British Columbia Computing Centre. The regression analyses were performed using the MULTIVAR program (Finn, 1968) and the BMD02R program (Dixon, 1968). The means and intercorrelations were calculated with the STRIP program available at the Computing Centre (Seagraves, 1971). The probability levels (p) for significance of the F-ratios were calculated using the local FPROB program (Dempster, 1969). All hypotheses having a significance level of less than .07 were used for substantive discussion and interpretation of the
The hypotheses given at the end of Chapter III were translated into statistical terms. The symbols used to represent the variables in this study are given in Table 11.

**Results of Analysis - Means**

Table 10 shows the means of the variables observed in the study for the total group and for the treatment groups taken separately. Although the difference between the means on most of the variables was not statistically significant, a consistent pattern was evident. The treatment groups were ranked in the hypothesized order \((T_1 > T_2 > T_3)\) on the posttest scores, total errors, total responses, proportion of errors, total correct in main lesson, number taking optional limit section, enjoyment and A-State main lesson. The main lesson latency was the exception, with the \(T_2\) group having a higher average response latency than the other two groups.

The results suggest that with the exception of latency, the correctional feedback variable had an effect on performance and learning in the expected direction, but that a more definitive result may have been obtained over a longer period of time or with a more difficult lesson.

The time of the CAI experimental session was coded '1' for the morning (9:00 a.m.), '2' for evening (5:30 p.m.) and
'3' for the weekend session. The means indicate that the three treatment groups were well balanced in each session except that the students in the third treatment group (T₃) attended slightly more experimental sessions (2) in the morning and the T₂ group attended the least sessions in the morning.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Pooled</th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Posttest</td>
<td>8.84</td>
<td>9.19</td>
<td>8.74</td>
<td>8.59</td>
</tr>
<tr>
<td>2. Time of Experimental Session*</td>
<td>1.76</td>
<td>1.86</td>
<td>1.81</td>
<td>1.62</td>
</tr>
<tr>
<td>3. Total Errors - main lesson</td>
<td>16.63</td>
<td>14.71</td>
<td>17.14</td>
<td>18.05</td>
</tr>
<tr>
<td>4. Total Responses - main lesson</td>
<td>27.60</td>
<td>26.48</td>
<td>28.10</td>
<td>28.24</td>
</tr>
<tr>
<td>5. Proportion of Errors - main lesson</td>
<td>0.58</td>
<td>0.53</td>
<td>0.57</td>
<td>0.63</td>
</tr>
<tr>
<td>7. Do you understand? - main lesson</td>
<td>0.76</td>
<td>0.71</td>
<td>0.76</td>
<td>0.81</td>
</tr>
<tr>
<td>8. Time to answer (7) above - main lesson</td>
<td>83.7</td>
<td>84.0</td>
<td>45.9</td>
<td>121.1</td>
</tr>
<tr>
<td>9. Had limit section - main lesson</td>
<td>0.79</td>
<td>0.62</td>
<td>0.81</td>
<td>0.95</td>
</tr>
<tr>
<td>10. Average First Latency - main lesson</td>
<td>116.4</td>
<td>118.0</td>
<td>123.7</td>
<td>107.4</td>
</tr>
<tr>
<td>11. Average Total Latency - main lesson</td>
<td>189.0</td>
<td>177.5</td>
<td>202.7</td>
<td>186.9</td>
</tr>
<tr>
<td>12. Enjoyment - main lesson</td>
<td>0.63</td>
<td>0.67</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>14. Prelesson Correct on first try</td>
<td>6.25</td>
<td>6.24</td>
<td>6.10</td>
<td>6.43</td>
</tr>
<tr>
<td>15. Average First Latency - prelesson</td>
<td>90.3</td>
<td>81.9</td>
<td>99.9</td>
<td>89.2</td>
</tr>
<tr>
<td>16. Average Total Latency - prelesson</td>
<td>119.4</td>
<td>108.2</td>
<td>134.0</td>
<td>115.8</td>
</tr>
<tr>
<td>17. Math Ability - first testing</td>
<td>31.08</td>
<td>30.86</td>
<td>30.24</td>
<td>32.14</td>
</tr>
<tr>
<td>18. Full A-State - first testing</td>
<td>46.9</td>
<td>47.3</td>
<td>46.5</td>
<td>46.8</td>
</tr>
<tr>
<td>19. A-Trait - first testing</td>
<td>41.8</td>
<td>41.3</td>
<td>43.1</td>
<td>41.2</td>
</tr>
<tr>
<td>20. Short A-State - first testing</td>
<td>9.6</td>
<td>8.8</td>
<td>10.2</td>
<td>9.8</td>
</tr>
<tr>
<td>21. A-State - prelesson</td>
<td>4.9</td>
<td>4.6</td>
<td>4.7</td>
<td>5.3</td>
</tr>
<tr>
<td>22. A-State - main lesson</td>
<td>11.9</td>
<td>11.2</td>
<td>12.0</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*This is a nominal variable. It is technically incorrect to calculate the mean and this value is merely intended here to serve as a crude shorthand comparison.
Results of Analysis - Hypothesis Testing

TABLE 11
SYMBOLS USED IN STATISTICAL ANALYSIS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Variable Represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y_1)</td>
<td>Posttest Score</td>
</tr>
<tr>
<td>(Y_2)</td>
<td>Proportion of errors in main lesson</td>
</tr>
<tr>
<td>(Y_3)</td>
<td>Average latency in main lesson</td>
</tr>
<tr>
<td>(X_1)</td>
<td>First contrast - mean of (T_1) vs. mean of (T_2)</td>
</tr>
<tr>
<td>(X_2)</td>
<td>Second contrast - mean of (T_2) vs. mean of (T_3)</td>
</tr>
<tr>
<td>(X_3)</td>
<td>Mathematical ability test score</td>
</tr>
<tr>
<td>(X_4)</td>
<td>Prelesson A-State score</td>
</tr>
<tr>
<td>(X_5)</td>
<td>Main lesson A-State score</td>
</tr>
<tr>
<td>(X_6)</td>
<td>Prelesson score</td>
</tr>
<tr>
<td>(X_7)</td>
<td>Prelesson average latency</td>
</tr>
</tbody>
</table>

Four separate regression equations were defined for the analysis, one for each of the three dependent measures and a last equation to test Hypothesis 5. The independent variables in these equations reflect the factors which
this investigator considered as important in this study.

An ordering logic was defined in testing the terms in the equations in a stepwise manner (Overall and Spiegel, 1970). The logic used involved entering learner characteristic terms first into the regression equation followed by treatment terms and then interaction terms. This means that treatment and interaction effects were tested with the effect of learner characteristics being controlled statistically. The four equations and the corresponding tables are given in the next section.

Posttest \((Y_1)\)

\[
T_1 = \begin{align*}
&\text{Treatment} \\
&\quad - 2.80X_1 + 2.32X_2 + .14X_3 + .26X_6 \\
&\quad \text{Math Ability} \\
&\quad .12X_1X_3 - .05X_2X_3 \\
&\quad \text{Prelesson} \\
&- .13X_1X_6 - .22X_2X_6 + .11X_1X_5 + .16X_2X_5 \\
&\text{error} \\
&\quad + \varepsilon
\end{align*}
\]
### TABLE 12

RESULTS OF REGRESSION ANALYSIS FOR POSTTEST

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$^{1}\Delta R^2$</th>
<th>Degrees of Freedom</th>
<th>$^{2}F_{obs}$</th>
<th>$^{3}p &lt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_3$</td>
<td>.166</td>
<td>1</td>
<td>13.92</td>
<td>.001</td>
</tr>
<tr>
<td>$X_6$</td>
<td>.032</td>
<td>1</td>
<td>2.68</td>
<td>.10</td>
</tr>
<tr>
<td>$X_5$</td>
<td>.044</td>
<td>1</td>
<td>3.69</td>
<td>.06</td>
</tr>
<tr>
<td>$X_1$</td>
<td>.000</td>
<td>1</td>
<td>.00</td>
<td>-</td>
</tr>
<tr>
<td>$X_2$</td>
<td>.005</td>
<td>1</td>
<td>.42</td>
<td>.53</td>
</tr>
<tr>
<td>$4(X_1 X_2)$</td>
<td>.005</td>
<td>2</td>
<td>.21</td>
<td>.81</td>
</tr>
<tr>
<td>$X_1 X_3$</td>
<td>.020</td>
<td>1</td>
<td>1.68</td>
<td>.20</td>
</tr>
<tr>
<td>$X_2 X_3$</td>
<td>.019</td>
<td>1</td>
<td>1.59</td>
<td>.21</td>
</tr>
<tr>
<td>$(X_1 X_3, X_2 X_3)$</td>
<td>.039</td>
<td>2</td>
<td>1.64</td>
<td>.20</td>
</tr>
<tr>
<td>$X_1 X_6$</td>
<td>.010</td>
<td>1</td>
<td>.84</td>
<td>.37</td>
</tr>
<tr>
<td>$X_2 X_6$</td>
<td>.016</td>
<td>1</td>
<td>1.34</td>
<td>.25</td>
</tr>
<tr>
<td>$(X_1 X_6, X_2 X_6)$</td>
<td>.026</td>
<td>2</td>
<td>1.09</td>
<td>.34</td>
</tr>
<tr>
<td>$X_1 X_5$</td>
<td>.053</td>
<td>1</td>
<td>4.44</td>
<td>.04</td>
</tr>
<tr>
<td>$X_2 X_5$</td>
<td>.027</td>
<td>1</td>
<td>2.26</td>
<td>.14</td>
</tr>
<tr>
<td>$(X_1 X_5, X_2 X_5)$</td>
<td>.080</td>
<td>2</td>
<td>3.36</td>
<td>.04</td>
</tr>
<tr>
<td>total</td>
<td>.392</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>error</td>
<td>.608</td>
<td>51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 $^{1}\Delta R^2$ represents the increment in $R^2$ given previous terms already entered in the equation.

2 $^{2}F_{obs} = \frac{R^2/df_1}{(1-R^2_{full}/df_{error})}$, where $df_1 = \text{number of degrees of freedom}$

for corresponding term(s) being tested.

$df_{full} = \text{number of degrees of freedom}$

for full model above.

$1-R^2_{full} = \Delta R^2_{error}$ as defined in table above.

3 Probability of making a Type I error by rejecting null hypothesis, i.e., claiming statistical significance.

4 Indicates that the individual terms in parentheses are tested as a set.
The results in Table 12 indicate that several variables were statistically significant in accounting for variation in the subjects' posttest scores (\(Y_1\)). The students' mathematical ability (\(X_3\)) was a highly significant variable (\(p < .001\)) in explaining posttest results. The main lesson A-State level (\(X_5\)) was statistically significant, (\(p < .06\)) controlling for the previous two variables. This finding would seem to indicate that a high level of anxiety may have existed even after the students completed the main lesson on the terminal. This was not surprising since the posttest was written immediately at the completion of the main lesson. A main lesson A-State-by-treatment interaction (\(p < .04\)) was obtained for posttest scores. In this case, the effect of anxiety (A-State) was different for subjects in \(T_1\) as compared with \(T_2\) (\(X_1X_5\)). A more detailed examination of this finding is given in figure 6.

The results for the hypotheses stated in Chapter III are given below for the posttest:

Hypothesis 1a: No significant difference was found in immediate learning between students provided with response-sensitive correctional feedback (\(T_1\)) and students provided with response-insensitive correctional feedback (\(T_2\)).
Hypothesis 1b: No significant difference was found in immediate learning between students provided with response-insensitive correctional feedback ($T_2$) and students provided with no correctional feedback ($T_3$).

Hypothesis 3: No significant interaction was found in terms of immediate learning between the $T_2$ versus $T_3$ groups and prerequisite skills.

Hypothesis 4: No significant interaction was found in terms of immediate learning between the $T_2$ versus $T_3$ groups and mathematical ability.
Proportion of Errors ($Y_2$)

\[ Y_2 = 0.22 X_1 - 0.06 X_2 - 0.004 X_3 - 0.005 X_4 \]

\[ \text{A-State} \]

\[ \text{Math Ability Prelesson} \]

\[ \text{Treatment} \]

\[ \text{A-State Main Prelesson} \]

\[ + 0.01 X_5 - 0.03 X_6 + 0.000 X_1 X_3 + 0.002 X_2 X_3 \]

\[ \text{Treatment} \]

\[ \text{x Math Ability} \]

\[ \text{Error} \]

\[ + 0.01 X_1 X_6 + 0.01 X_2 X_6 + 0.002 X_1 X_5 - 0.004 X_2 X_5 + e \]

**TABLE 13**

RESULTS OF REGRESSION ANALYSIS FOR PROPORTION OF ERRORS

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$\Delta R^2$</th>
<th>Degrees of Freedom</th>
<th>Fobs</th>
<th>p &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_3$</td>
<td>0.094</td>
<td>1</td>
<td>7.53</td>
<td>0.01</td>
</tr>
<tr>
<td>$X_6$</td>
<td>0.096</td>
<td>1</td>
<td>7.69</td>
<td>0.01</td>
</tr>
<tr>
<td>$X_4$</td>
<td>0.008</td>
<td>1</td>
<td>0.64</td>
<td>0.43</td>
</tr>
<tr>
<td>$X_5$</td>
<td>0.068</td>
<td>1</td>
<td>5.23</td>
<td>0.02</td>
</tr>
<tr>
<td>$X_1$</td>
<td>0.004</td>
<td>1</td>
<td>0.32</td>
<td>0.58</td>
</tr>
<tr>
<td>$X_2$</td>
<td>0.059</td>
<td>1</td>
<td>4.72</td>
<td>0.03</td>
</tr>
<tr>
<td>($X_1, X_2$)</td>
<td>0.063</td>
<td>2</td>
<td>2.02</td>
<td>0.14</td>
</tr>
<tr>
<td>$X_1 X_3$</td>
<td>0.006</td>
<td>1</td>
<td>0.48</td>
<td>0.50</td>
</tr>
<tr>
<td>$X_2 X_3$</td>
<td>0.007</td>
<td>1</td>
<td>0.56</td>
<td>0.46</td>
</tr>
<tr>
<td>($X_1 X_3, X_2 X_3$)</td>
<td>0.013</td>
<td>2</td>
<td>0.52</td>
<td>0.60</td>
</tr>
<tr>
<td>$X_1 X_5$</td>
<td>0.019</td>
<td>1</td>
<td>1.52</td>
<td>0.22</td>
</tr>
<tr>
<td>$X_2 X_6$</td>
<td>0.007</td>
<td>1</td>
<td>0.56</td>
<td>0.46</td>
</tr>
<tr>
<td>($X_1 X_6, X_2 X_6$)</td>
<td>0.026</td>
<td>2</td>
<td>1.04</td>
<td>0.36</td>
</tr>
<tr>
<td>$X_1 X_5$</td>
<td>0.000</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$X_2 X_5$</td>
<td>0.008</td>
<td>1</td>
<td>0.64</td>
<td>0.43</td>
</tr>
<tr>
<td>($X_1 X_5, X_2 X_5$)</td>
<td>0.008</td>
<td>2</td>
<td>0.32</td>
<td>0.73</td>
</tr>
<tr>
<td>total</td>
<td>0.376</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>error</td>
<td>0.624</td>
<td>50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It should be noted that HELP and NOMATCH responses were counted as errors and responses. Also, responses that were made when a subject repeated a section of the main lesson were ignored except for the last instructional unit in the sequence. The results of the students' performance on this last instructional unit were combined for the two times that the student attempted the unit.

The results given in Table 13 for proportion of errors \( (Y_2) \) indicate that mathematical ability and prelesson score were both statistically significant at the .01 level. The main lesson A-State level was statistically significant \( (p<.02) \) in predicting proportion of errors on the main lesson.

A significant treatment effect was found in comparing the \( T_2 \) and \( T_3 \) group means \( (p<.03) \) with regard to proportion of errors. There were no significant trait-treatment interactions.

The results of the hypotheses stated in Chapter III are given below for proportion of errors:

**Hypothesis 1a:** No significant difference was found in proportion of errors between students provided with response-sensitive correctional feedback \( (T_2) \) and students provided with response-insensitive correctional feedback \( (T_3) \).
Hypothesis 1b: A significant difference was found in proportion of errors between students provided with response-insensitive correctional feedback (T2) and students provided with no correctional feedback (T3).

Hypothesis 3: A significant interaction was found in terms of proportion of errors between the T2 versus T3 groups and prerequisite skills.

Hypothesis 4: No significant interaction was found in terms of proportion of errors between the T2 versus T3 groups and mathematical ability.

Average Latency (Y3)

\[ Y_3 = 14.92 X_1 - 122.54 X_2 - 1.47 X_3 - 6.66 X_4 \]

\[ \text{A-State Main:} \quad + .50 X_5 \quad + 9.22 X_6 \quad + .59 X_7 \]

\[ \text{Math Ability:} \quad + 1.63 X_1 X_3 - .10 X_2 X_3 \]

\[ \text{Prelesson Latency:} \quad - .78 X_1 X_5 + 4.72 X_2 X_5 \quad + .24 X_1 X_7 - .01 X_2 X_7 + e \]
TABLE 14

RESULTS OF REGRESSION ANALYSIS FOR AVERAGE LATENCY

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$R^2$</th>
<th>Degrees of Freedom</th>
<th>Fobs</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_3$</td>
<td>.156</td>
<td>1</td>
<td>13.57</td>
<td>.001</td>
</tr>
<tr>
<td>$X_6$</td>
<td>.028</td>
<td>1</td>
<td>2.30</td>
<td>.13</td>
</tr>
<tr>
<td>$X_4$</td>
<td>.061</td>
<td>1</td>
<td>5.02</td>
<td>.03</td>
</tr>
<tr>
<td>$X_7$</td>
<td>.128</td>
<td>1</td>
<td>11.14</td>
<td>.002</td>
</tr>
<tr>
<td>$X_5$</td>
<td>.001</td>
<td>1</td>
<td>.09</td>
<td>.76</td>
</tr>
<tr>
<td>$X_1$</td>
<td>.006</td>
<td>1</td>
<td>.52</td>
<td>.48</td>
</tr>
<tr>
<td>$X_2$</td>
<td>.002</td>
<td>1</td>
<td>.18</td>
<td>.68</td>
</tr>
<tr>
<td>$X_1X_2$</td>
<td>.008</td>
<td>2</td>
<td>.35</td>
<td>.71</td>
</tr>
<tr>
<td>$X_1X_3$</td>
<td>.003</td>
<td>1</td>
<td>.26</td>
<td>.62</td>
</tr>
<tr>
<td>$X_2X_3$</td>
<td>.001</td>
<td>1</td>
<td>.09</td>
<td>.76</td>
</tr>
<tr>
<td>$(X_1X_3,X_2X_3)$</td>
<td>.004</td>
<td>2</td>
<td>.17</td>
<td>.84</td>
</tr>
<tr>
<td>$X_1X_6$</td>
<td>.009</td>
<td>1</td>
<td>.78</td>
<td>.39</td>
</tr>
<tr>
<td>$X_2X_6$</td>
<td>.005</td>
<td>1</td>
<td>.43</td>
<td>.52</td>
</tr>
<tr>
<td>$(X_1X_6,X_2X_6)$</td>
<td>.014</td>
<td>2</td>
<td>.61</td>
<td>.55</td>
</tr>
<tr>
<td>$X_1X_5$</td>
<td>.006</td>
<td>1</td>
<td>.52</td>
<td>.48</td>
</tr>
<tr>
<td>$X_2X_5$</td>
<td>.048</td>
<td>1</td>
<td>4.18</td>
<td>.04</td>
</tr>
<tr>
<td>$(X_1X_5,X_2X_5)$</td>
<td>.054</td>
<td>2</td>
<td>2.35</td>
<td>.10</td>
</tr>
<tr>
<td>$X_1X_7$</td>
<td>.007</td>
<td>1</td>
<td>.61</td>
<td>.44</td>
</tr>
<tr>
<td>$X_2X_7$</td>
<td>.000</td>
<td>1</td>
<td>.00</td>
<td>.10</td>
</tr>
<tr>
<td>$(X_1X_7,X_2X_7)$</td>
<td>.007</td>
<td>2</td>
<td>.30</td>
<td>.67</td>
</tr>
<tr>
<td>total</td>
<td>.461</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>error</td>
<td>.539</td>
<td>47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The results shown in Table 14 indicate the mathematical ability \((p < .001)\), prelesson A-State \((p < .03)\) and prelesson average latency \((p < .002)\) are all statistically significant in terms of predicting average main lesson latency \((Y_3)\).

A significant main A-State-level-by-treatment interaction was obtained \((p < .04)\) for the \(T_2\) and \(T_3\) treatment groups. This finding is examined in more detail in figure 8.

The results of the hypotheses stated in Chapter III are given below for average response latency:

**Hypothesis 1a:** No significant difference was found in average response latency between students provided with response-sensitive correctional feedback \((T_1)\) and students provided with response-insensitive correctional feedback \((T_2)\).

**Hypothesis 1b:** No significant difference was found in average response latency between students provided with response-insensitive correctional feedback \((T_2)\) and students provided with no correctional feedback \((T_3)\).
Hypothesis 2: A significant interaction (p < .04) was found in terms of average response latency between the T₂ versus T₃ groups and A-State. See figure 7.

Hypothesis 3: No significant interaction was found in terms of average response latency between the T₂ versus T₃ groups and prerequisite skills.

Hypothesis 4: No significant interaction was found in terms of average response latency between the T₂ versus T₃ groups and mathematical ability.

Relationship Between Process and Product

\[
Y_1 = \frac{-0.05 \times X_1 - 0.03 \times X_2 + 0.09 \times X_3 - 0.01 \times X_4}{-0.10 \times X_5 + 0.09 \times X_6 - 0.01 \times X_7} - \frac{5.56 \times Y_2}{0.005 \times Y_3 + e}
\]
TABLE 15
RESULTS OF REGRESSION ANALYSIS FOR HYPOTHESIS 5

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>$\Delta R^2$</th>
<th>Degrees of Freedom</th>
<th>Fobs</th>
<th>P&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(X_1, X_2, X_3, X_4, X_5, X_6, X_7)$</td>
<td>.261</td>
<td>7</td>
<td>2.62</td>
<td></td>
</tr>
<tr>
<td>$Y_2$</td>
<td>.042</td>
<td>1</td>
<td>3.22</td>
<td>.07</td>
</tr>
<tr>
<td>$Y_3$</td>
<td>.006</td>
<td>1</td>
<td>0.46</td>
<td>.46</td>
</tr>
<tr>
<td>$(Y_2, Y_3)$</td>
<td>.048</td>
<td>2</td>
<td>1.82</td>
<td>.17</td>
</tr>
<tr>
<td>total</td>
<td>.309</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>error</td>
<td>.691</td>
<td>53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results in Table 15 indicate that proportion of errors ($Y_2$) was linearly related ($p<.07$) to posttest score ($Y_1$) with the effect of learner characteristics and treatment difference statistically controlled. No relationship was found between average latency ($Y_2$) and posttest ($Y_1$).

Hypothesis 5: A significant linear relationship ($p<.07$) was found between immediate learning and proportion of errors with the effect of learner characteristics and treatment statistically removed.
The graph shown in figure 6 illustrates the differential effect of A-State on posttest (raw) scores for the three treatment groups. An increase in A-State caused a decrement in posttest performance. However, the linear relationship between posttest score and A-State was only statistically significant for the T2 treatment group. The interaction between the A-State and correctional feedback was merely ordinal, i.e. the regression lines did not cross.

The graph shown in figure 7 illustrates the relationship between average latency in the main lesson and main A-State. For the T1 and T2 treatment groups, an increase in A-State was not statistically significant. For the T3 group (no correctional feedback) an increase in A-State level led to a significant increase in response latency. The interaction between A-State and correctional feedback was merely ordinal, i.e. the regression lines did not cross.
Regression Lines of Posttest \(Y_1\) and Main Lesson A-State \(X_5\) for \(T_1\), \(T_2\), \(T_3\)

\[ *T_1: \quad Y_1 = 9.2 - 0.09 X_5 \]
\[ T_2: \quad Y_1 = 8.7 - 0.44 X_5 \]
\[ T_3: \quad Y_1 = 8.6 - 0.05 X_5 \]

Figure 6
Figure 7

Regression Lines of Average Main Lesson Latency ($Y_3$) and Main A-State ($X_3$) for the Three Treatment Groups.

*T1: $Y_3 = 177.5 - 0.68X_5$
*T2: $Y_3 = 202.7 - 1.25X_5$
*T3: $Y_3 = 186.9 - 5.55X_5$
Results of Post hoc Analysis

Table 17 in Appendix H lists the correlation coefficient estimates between all pairs of variables observed in the study for the total sample of sixty-three subjects. The reader should note that a correlation coefficient which is statistically significant provides additional insight into the data but does not allow causal inferences to be made.

The extremely high correlations (> .95) of proportion of errors (4) with total errors (2) and with total responses (3) suggests that either of the latter two variables could have been used as criterion measures in place of proportion of errors (2 divided by 3) with no important differences in results.

The extremely high correlation (.94) between latency for the first response of an instructional unit in the prelesson (14) and total latency for that instructional unit (15) indicates that either of these two measures could have been used as independent variables in the experiment. The total latency (15) was actually used. Similarly, the high correlation (.81) between first time latency (9) in the main lesson and total latency (10) indicates that either variable could have been used as a criterion variable. The total latency was actually used.
The results in Table 17 show that mathematical ability (16) is the most important variable. This variable (16) is correlated significantly with posttest (1), errors (2,4,5), latency in the prelesson (14, 15) and latency in the main lesson (9, 10).

At one point in the main lesson the student was asked the question, "Do you understand?" The correlation between the response to this question (6) and time to answer the question (7) was significant (-.58) which indicated that people who answered "yes" took less time to respond.

A significant correlation (-.35) was found between the main lesson A-State (21) and the students' enjoyment of the lesson (11) as measured by a question at the end, "Did you enjoy this method of learning?" Lower A-State level was related to more enjoyment of the CAI experience.

A positive correlation (.33) was found between proportion of errors (4) and whether the students went through the optional section on limits (8). Students with a higher proportion of errors tended to opt for taking the limit section during the main lesson.

Surprisingly, there was no relationship found between trait anxiety, A-Trait (18) as measured in the first testing session, and the state anxiety, A-State during the prelesson (20) or the main lesson (21). However, a
significant linear relationship (.38) was found between A-Trait and the five-item A-State score (19) measured on the DAY 1 paper and pencil test.

Table 18 in Appendix H lists a comparison of correlation coefficients between selected variables for the three treatment groups considered separately. The Chi-square value indicates whether the three correlation coefficients are significantly different at the five percent level.

The only statistically significant finding was the correlation between posttest score and the total number of main lesson correct responses given by the student before being given the answer by the computer. A positive correlation (> .55) was found for the two groups receiving feedback information (T₁ and T₂) but no relationship (r = .07) for the group receiving no feedback information (T₃).

The graph in figure 8 illustrates the average number of errors made by the total group on each instructional unit in the main lesson. The results indicate the students made relatively few errors during the main lesson. The subjects averaged more than two errors only on one instructional unit (9) and on units 12, 13 and 14, the students averaged almost two errors. This finding indicates
that the correctional feedback variable may not have been potent enough to significantly differentiate between the T₁ and T₂ treatment groups. The reason for this is that feedback was rarely received from more than one or two wrong answer categories before the computer provided the answer to the student. Also, in some cases many students provided the correct response without making an error, as in units 2, 3, 4, 5, 6, 10 and 11. However, a higher error rate program would have been self-defeating in terms of the goal of efficiency in learning. Another trend was noted in that the difficulty levels of the instructional units were not evenly distributed since the lesson fluctuated several times from easy to difficult.

The graph in Figure 9 shows the average number of errors made on each instructional unit for the three treatment groups taken separately. On the more difficult units such as 7, 9 and 12, the superiority of the T₁ group was evident. On instructional unit 9, which was the only unit where all groups averaged more than two errors, the ranking of average number of errors was as hypothesized \((T₁ < T₂ < T₃)\). This finding suggests that the results expected in the study may have been more pronounced if the error rate of the lesson had been higher.
Figure 8

Graph of Errors on Instructional Units for Combined Groups
Figure 9

Graph of Errors on Instructional Units for $T_1$, $T_2$, $T_3$
The graph in figure 10 shows the average total response latency on each instructional unit for the three treatment groups. Although no obvious trend seemed to have occurred, one clear finding emerged. The subjects in the second treatment group (T2) took more time to respond on nearly all difficult instructional units from the seventh unit onward. For example, examining instructional units 7, 9, 12, 13 and 14, the T2 subjects had larger average latency values. As noted earlier, the T2 group attended the fewest morning sessions and so it is possible that after a day of classes, a fatigue effect became predominant in the second half of the main lesson.

The graph in figure 11 shows the A-State levels for the three treatment groups at different points in time during the study. The graph illustrates that on DAY 1 and during the prelesson, the A-State level of T2 subjects was higher than that of T3 subjects who, in turn, had higher A-State levels than the T1 subjects. This seems to indicate that the T2 subjects were more anxious than the others. However, during the main lesson, the relative A-State levels were all significantly higher and the ranking in this case was as expected (T1 < T2 < T3).

A group of fifteen subjects reviewed a portion of the main lesson and was presented with the A-State instrument
twice. Six subjects were in the $T_1$ group, five were in the $T_2$ group and four were in the $T_3$ group. The mean A-State score of these students the first time through the main lesson was 13.1. After reviewing a section of the lesson and repeating the A-State questionnaire, their A-State level was 14.6. This indicates that A-State level was increasing with time at this stage of the experiment and was probably quite high when the students wrote the posttest. Unfortunately, the A-State level was not obtained during the posttest but the fatigue effect evident for the $T_2$ group in terms of latencies may have caused a reversal of the relative order of A-State for the three groups.

It is evident that more difficult items would have increased the A-State level even more and probably would have better separated the three groups in terms of anxiety.
Figure 10

Graph of Latencies on Instructional Units for $T_1$, $T_2$, $T_3$
Figure 11

Graph of A-State Levels During Experiment
TABLE 16

AVERAGE NUMBER OF RESPONSES IN EACH RESPONSE CLASS FOR MAIN LESSON

<table>
<thead>
<tr>
<th>Response Class</th>
<th>Average Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$T_1$</td>
</tr>
<tr>
<td>HELP</td>
<td>0.8</td>
</tr>
<tr>
<td>Correct Answer</td>
<td>11.6</td>
</tr>
<tr>
<td>Wrong Answer 1</td>
<td>3.5</td>
</tr>
<tr>
<td>Wrong Answer 2</td>
<td>3.2</td>
</tr>
<tr>
<td>Wrong Answer 3</td>
<td>1.3</td>
</tr>
<tr>
<td>NOMATCH</td>
<td>5.4</td>
</tr>
</tbody>
</table>

The results shown in Table 16 indicate that the $T_1$ group asked for help on the average less than once in the main lesson. This was significantly fewer times than the other two groups ($T_2$, $T_3$).

The average number of correct responses made were ranked in the expected order, although the differences between the three groups were not significant.

It is interesting to note that as less correctional feedback was provided from $T_1$ to $T_3$, the number of unanticipated (NOMATCH) responses increased slightly.
The average number of unanticipated responses for the fifteen unit main lesson was approximately six. This is a very respectable figure in view of the fact that many of the errors were typing or notation errors. Therefore, limitations of the CAI author language did not seriously hamper the recognition of student responses in this experiment.

A fair balance was achieved for the wrong answer classes except that few responses fell into the third class. Some improvement could be made here in better anticipating student incorrect responses.

**Summary of Statistical Results**

The regression analysis produced several findings. The results of the posttest analysis indicate that mathematical ability \( (p < .001) \) was significant in predicting immediate learning. However, when the effect of this variable and the other variables stated in Hypothesis 5 was removed, the proportion of errors for the main lesson was also significant \( (p < .07) \) in predicting posttest results.

The expected difference between the three treatment groups receiving different types of correctional feedback was not observed on the posttest. An unexpected finding occurred in that the main lesson A-State level was
significant in predicting posttest performance \( (p < .06) \)
and an A-State-by-treatment interaction was found \( (p < .04) \)
in predicting posttest scores.

The effect of state anxiety on posttest performance was different for students in the \( T_1 \) group compared to students in the \( T_2 \) group. Graphical analysis showed that a significant decrement in posttest performance occurred when A-State increased, but only for the \( T_2 \) group.

The results of the regression analysis for proportion of errors indicated that mathematical ability \( (p < .01) \) and prelesson score \( (p < .01) \) were both statistically significant. Also, the A-State level was significant \( (p < .02) \) in predicting the main lesson proportion of errors. No significant interactions were observed.

The expected treatment effect was observed. A significant difference in proportion of errors \( (p < .03) \) was found between the \( T_2 \) and \( T_3 \) treatment groups. This difference was in the expected direction, i.e. the \( T_3 \) group had a higher proportion of errors than the \( T_2 \) group.

The results of the regression analysis for average response latency indicated that, once again, mathematical ability was highly significant \( (p < .001) \) in predicting performance. The A-State level that was reached during the prelesson was significant in predicting response latency
during the main lesson ($p < .03$). As would be expected, the prelesson average latency was statistically significant ($p < .002$) in predicting the main lesson average latency. The expected treatment effect was not observed since no significant differences were found between the three treatment groups on response latency. However, the expected A-State-by-treatment interaction for latency was observed ($p < .04$).

The effect of state anxiety on response latency was different for students in the $T_2$ group compared to students in the $T_3$ group. Graphical analysis showed that a significant increase in average response latency occurred with an increase in state anxiety for the $T_3$ treatment group only.

The post hoc analysis provided some useful information for interpretation of the results and suggested some other questions. The table of means further indicated that the $T_2$ group attended the fewest morning sessions and the $T_3$ group attended the most. This finding suggests that the longer latencies may have been due to a fatigue effect. This would have been caused by the slight predominance of evening sessions for the $T_2$ group.

An interesting finding was the significant correlation ($r = -.35$) between enjoyment of the main lesson and level
of A-State. As might be expected, the low A-State students enjoyed this method of learning more than the high A-State students.

The significant correlation between proportion of errors and whether or not students had the optional limit section \((r = .33)\) suggests that students realized when they required extra assistance and that, therefore, more learner control could be built into the CAI lessons.

An examination of the HELP and NOMATCH options showed that the \(T_1\) group asked for help significantly fewer times than the other two groups \((T_2, T_3)\). This finding again provides support for more learner control of instruction. The number of unrecognized responses (NOMATCH) were ranked as expected \((T_1 \leq T_2 \leq T_3)\). Therefore, increased information in the correctional feedback seems to provide a partial solution to the problem of anticipating all possible incorrect responses.

The table of means showed that the three treatment groups differed on nearly all of the important variables in the direction expected, but that the effects were not statistically significant.

The graphs of errors showed that the program had a low error rate despite efforts by the experimenter to utilize a sample that would find the material difficult.
Only one instructional unit had an average of more than two errors for the total group. It is interesting to note that a large difference was found in the expected direction in terms of errors on this instructional unit among the three groups.

The graph of latencies indicated that the units were uneven in difficulty and that the T2 group took consistently longer on the instructional units in the second half of the main lesson.

The graph of A-State over time indicated that the expected pattern in anxiety did occur but that the difference between the three groups was not as pronounced as expected. The total group, however, did increase in A-State during the main lesson, as expected.
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of Study

This study was undertaken to investigate the use of computer-assisted instruction as an instructional laboratory. The concept of an instructional logic was defined as an algorithm followed by the computer program for each instructional unit. This step-by-step logic was repeated for each instructional unit but with different content.

This procedure permitted the controlled manipulation of the variable of correctional feedback. Three forms of correctional feedback were defined by varying the information content of the feedback. These were response-sensitive correctional feedback, response-insensitive correctional feedback and no correctional feedback (only that the answer was incorrect).

The interaction of correctional feedback with selected learner characteristics was examined as well. These learner traits were mathematical ability, prerequisite knowledge and state anxiety. The effect of correctional feedback and its
interaction with these variables was examined.

Subjects of the study were a representative sample of sixty-three preservice elementary school teachers from five sections of a mathematics course given in a large education faculty. These subjects were randomly assigned to the three treatment conditions, although they selected the CAI experimental periods in which they would participate. The test of mathematical ability used was the Cooperative Sequential Test of Educational Progress, Mathematics Form 2A (STEP). The state anxiety instrument used was the State-Trait Anxiety Inventory (STAI) and the five item short form used by O'Neil (1972) was administered twice. The eighteen item posttest was constructed by the experimenter and the measure of prerequisite knowledge used was a nine item prelesson with a possible mark of 0, 1 or 2 on each item.

The mathematics lesson was a topic in introductory calculus dealing with the concept of derivative. The topic was treated from a physical point of view, using concepts of distance, speed and time to illustrate the mathematical concepts. The main objectives were to show that the derivative is a limit and to show how to use this limit definition to calculate the derivative of a function at a point.
The CAI lesson was programmed using an author language developed by the experimenter as a vehicle for implementing the instructional logic and varying the correctional feedback. The language is limited in use but has the advantage of requiring essentially no computer experience of an instructional designer. The main limitation of the language as implemented at the University of British Columbia is the cost, which severely limited the sample size in this experiment.

The results of the study were generally in the expected direction but the effects were not as pronounced as had been hypothesized. The most important finding was the significant difference in proportion of errors on the main lesson between the $T_2$ and $T_3$ groups. The importance of this finding was then increased by the significant relationship found between immediate learning and proportion of errors with the effect of learner traits and treatment effects statistically removed.

The most effective variable in predicting performance in the experiment was mathematical ability and its effect was statistically controlled when testing the effect of the other variables. Prerequisite knowledge was also important in predicting performance and was statistically controlled as well. State anxiety was significant in predicting
response latency but not in predicting errors. Significant treatment by A-State interactions were observed for posttest and for response latency.

The three treatment groups differed in the expected direction on most of the important variables but the differences were not statistically significant. In particular, the A-State levels for the three groups were ordered as expected, but the differences were not large enough to cause the hypothesized interactions.

The results of the study partially supported the hypothesis of the important role of correctional feedback in instruction and its interaction with individual traits of the learner.

Finally, the possibility of a confounding variable became evident. A fatigue effect for the T_2 group seemed possible in light of the slight predominance of evening sessions coupled with the larger response latencies for this group.

In general, the two goals of this project were attained. A methodology was developed for CAI as an instructional laboratory and this methodology was used successfully to perform a controlled experiment. This experiment provided evidence that correctional feedback leads to improved performance during learning compared with
feedback telling a student merely that his response is incorrect. A significant relationship was found between proportion of errors and posttest score which suggests that a number of errors made during a lesson is a measure that can be used to maximize immediate learning.

Finally, the variable of state anxiety was examined and was found to negatively affect response latency. Also, state anxiety increased when no correctional feedback was provided to the students as well as when the content became more difficult. This finding confirmed the expected relationship between state anxiety and task difficulty.

Discussion of Findings

Correctional feedback. The correctional feedback variable had some effect in this experiment. A significant difference (p < .03) in proportion of errors was observed between the group receiving response-insensitive correctional feedback (T2) and the group receiving no correctional feedback (T3). The raw means of the three groups on most of the variables examined in the study were ranked in the expected order, i.e. T1 > T2 > T3. However, the differences were not statistically significant.

The results suggest that the response-insensitive correctional feedback (T2) may be optimal since some helpful information is provided to the student after an
incorrect response but prior analysis of all possible responses (and keywords) is not required. This form of correctional feedback requires far less time to prepare by the instructional programmer and much less computer time and storage is used. More definitive results may have been obtained with a lesson having a higher error rate, but this would have been self-defeating since the aim of the program was to help the student succeed. These results suggest that in terms of using CAI in the schools, programmed instructional materials can emulate the $T_2$ strategy quite easily and cheaply. Until effective response-sensitive feedback can be developed which can be demonstrated to cause improved performance and learning, the use of CAI in the classroom is not justified. However, using CAI as an instructional laboratory permits research to be carried out that could not be done using programmed-instructional materials.

**A-State.** As expected, the relative difficulties of the three treatment conditions caused corresponding differences in A-State level during the lesson. However, these A-State levels were not significantly different for the three treatment groups. For all groups, the A-State level did increase in the main lesson compared to the written test and prelesson. Also, a few students in each group
repeated a section and were given the A-State questions again. The mean A-State level for these twelve students again increased substantially suggesting that A-State levels were increasing towards the end of the CAI session.

The hypothesized A-State-by-correctional-feedback interaction did not occur for proportion of errors, but an interaction did occur for the other two criterion variables. An increase in A-State for the T3 group (no correctional feedback) was coupled with a significant increase in response latency. There was no significant relationship between A-State and response latency for the T1 and T2 groups. This finding again provided evidence in favor of response-insensitive correctional feedback (T2) as the optimal condition.

An unexpected finding occurred for the T2 group. An increase in main lesson A-State for this group was related to a decrease in posttest performance. Unfortunately, this finding is difficult to interpret because the actual A-State level during the written posttest was not obtained. It is possible that these A-State levels may have been substantially different from the main lesson since A-State anxiety levels were increasing towards the end of the main lesson, as pointed out above. The explanation offered at this point for this finding is that a fatigue effect may have
been present and may have affected the $T_2$ group. The reason for this statement is that students in the $T_2$ group took consistently longer to respond during the second half of the main lesson and were probably most fatigued. A possible explanation for this is the fact that slightly more $T_2$ students took the CAI lesson and posttest after classes in the evening, despite efforts by the experimenter to control for this factor.

The main lesson A-State was significant in predicting proportion of errors for the total group. Also, the prelesson A-State was significant ($p<.03$) in predicting the main lesson response latency. Therefore, the relationship between anxiety and performance for the whole group was well established in this study. Surprisingly, no relationship was found between A-Trait and main lesson A-State levels.

Tobias (1973) suggested that it may be that the variable of anxiety, while useful in other areas, has limited utility in the area of individualized instruction. The reason for this statement is that in individualized instructional contexts an attempt is made to minimize difficulty in order to have a high ratio of success. Even when instructional materials are experimentally altered to increase their difficulty, these alterations are often
insufficient to both evoke and maintain levels of anxiety sufficient to exert significant debilitating effects on achievement. This may explain the lack of stronger findings in this particular study.

**Mathematical ability.** The variable of mathematical ability had the most evident effect in the study. This variable was highly significant in predicting immediate learning, proportion of errors and response latency. However, the hypothesized correctional feedback-by-mathematical-ability interaction was not observed for any of the criterion variables. This finding suggests that mathematical ability may not be a useful variable for individualizing instruction and that more specific abilities known to be important to task performance are required.

**Prerequisite knowledge.** The variable of prerequisite knowledge, as measured on the prelesson, was found to be significant in predicting proportion of errors ($p < .01$) only. This finding is reasonable since it would seem that a good predictor of main lesson performance on a CAI lesson during the main lesson would be the performance on CAI prelesson. In line with this reasoning, the prelesson average response latency was significant ($p < .002$) in predicting the main lesson average response latency.
The hypothesized prerequisite knowledge-by-correctional feedback interaction was not observed for any of the criterion variables. This finding seems to have been caused by the lack of variance in the prelesson scores for subjects in the experiment. Most students already had attained the prerequisite objectives and the prelesson served merely as a warm-up for them.

**Relationship between process and product.** A significant linear relationship ($p < .07$) was observed between the process variable (proportion of errors) and the product variable (immediate learning). No such relationship was observed between response latency and immediate learning. However, there is some suggestion in the literature (Judd et al., 1973) that response latency may have an effect on retention. The above significant relationship was observed after the effect of all learner variables in the study and treatment had been statistically removed (partialled out).

The finding that providing response-insensitive correctional feedback ($T_2$) is better than providing no correctional feedback ($T_3$) for reducing proportion of errors and that a significant relationship (negative correlation) exists between proportion of errors and immediate learning has important implications. The final goal of the
instruction is to maximize the learning product which is what the student takes with him when he leaves the CAI terminal. The evidence from this study suggests that response-insensitive correctional feedback is the optimal condition to achieve this goal at the least cost.

Post hoc analysis results. The post hoc analysis provided some useful information for interpretation of the results and suggested some further questions. The correlational analysis also indicated that mathematical ability had the strongest effect in this experiment. It was noted that a significant correlation ($r = -0.35$) occurred between main lesson A-State and enjoyment of this method of learning. Students with lower A-State levels tended to enjoy the lesson more.

Two findings that have implications for future CAI work were: (1) there was a significant correlation ($r = 0.33$) between proportion of errors and whether or not students chose the optional section on limits, and (2) the number of students in each group that had the limit section increased from $T_1$ to $T_2$ to $T_3$ and the $T_1$ group asked for help significantly fewer times than the other two groups. These findings suggest that students realize when they require extra assistance and that more learner control of instruction could be built into CAI lessons.
The only correlational coefficient significantly different for the three groups taken separately was the correlation between posttest score and number of main lesson correct responses given by the student before the computer provided the answer. The correlation ($r \geq 0.55$) for the $T_1$ and $T_2$ groups suggests that students who find the correct response themselves during the lesson will perform better on the posttest. This result suggests that correctional feedback information is an important part of this learning process. This finding also raises the question about the motivational properties of correctional feedback since no significant correlation was found when correctional feedback was not provided ($T_3$).

The table of means indicates that the three treatment groups differed on nearly all of the important variables in the expected direction, but that effects were not statistically significant. The variables referred to are posttest score, total errors, total responses, proportion of errors, total correct, number of students taking optional limit section, enjoyment and main lesson A-State level.

The graphs of errors show that the program had a low error rate despite efforts by the experimenter to utilize a sample of students who would make many errors. Only one instructional unit had an average of more than
two errors for the total group. This instructional unit produced large differences in the expected direction between the three groups, suggesting that a more difficult lesson may have produced more definitive results. A more difficult lesson could be designed by dealing with more content in each instructional unit than was dealt with in this study.

The graph of latencies shows that the instructional units were uneven in difficulty and that the T₂ group took consistently longer on the units in the second half of the main lesson, thereby producing a fatigue effect that may have affected the results.

Limitations of the Study

A most apparent limitation of this study, and other studies in the area of CAI at the present time, is the cost factor. This factor was the major constraint in limiting the sample size in this study to sixty-three students. Unless an institution is willing to invest funds in this type of research, it is probably wiser to limit CAI research to institutions having the specialized hardware and software facilities required for efficient CAI.

The biggest difficulty for the students seemed to be the notation used by the computer. Since a standard typewriter ball was used, symbols for change (Δ) and a
normal division sign could not be used. Also, variables could not be raised to a power using the usual notation. An examination of the students work sheets indicated that they often did their calculations using their own notation and then entered the answer using the computer's cumbersome notation. Therefore, the hardware limitations probably had an effect on the experimental results. Bork and Sherman (1971) also noted this limitation.

The students in the experiment were preservice elementary school teachers and so the generalizability of the results is limited to this or similar populations of students. The content of the CAI lesson dealt with a well structured mathematical algorithm which was derived in the lesson and applied to concrete examples. Since content may act to moderate the effects of other variables, the generalizability of the results is limited to material having similar structure.

An obvious limitation was the short term nature of the experiment. The differences that did occur may not have been observed over a longer period of time. Also, a novelty effect was certainly present and may have affected the results. Once again, this is a cost limitation of much of the present CAI research because the time required to develop a full term CAI course is enormous for a single person.
An unexpected fatigue effect seemed to have affected the results. This effect was not observed in the pilot group of college students in Montreal but seemed to be a factor in this study, particularly during the posttest.

Recommendations for Further Research

Although some treatment effects were observed in this study, these were not definitive due to the lack of large enough differences in treatment between the $T_1$ and $T_2$ groups. A study similar to the present one should be conducted with a more difficult lesson and this could be done by increasing the material treated in each instructional unit.

An attempt should be made to design a longer term study where a student would come more often to the CAI terminal, but for less time in order to minimize fatigue effects. Possibly a team effort would best facilitate this type of study.

The organizational scheme given in Chapter I generates many questions. The independent variables may have an effect on retention and transfer, and these should also serve as criterion variables for further studies.

Other learner variables should be examined, such as motivational variables and verbal aptitude. These should come from an adequate prior conceptual analysis of the
treatment. Other CAI lesson variables should be studied, such as types of branching and degree of learner control.

Similar studies utilizing different populations, particularly elementary and secondary school students, would certainly be desirable as would be studies in a variety of subject areas. This would increase the generalizability of the results.

A CRT (graphics) terminal would possibly reduce the fatigue effect in further studies. An attempt should be made to assess the effects of a variety of CAI terminal types.

It has been noted that sex may be an important variable in anxiety studies. Further studies should attempt to look at the effect of this variable.

Final Comment

As with many other studies, the present one had weaknesses and produced some unanticipated results. However, a major goal of the study was achieved: the demonstration that CAI is a powerful and valuable means to examine instruction for the purpose of producing a scientifically-based theory of instruction. It is hoped that this study will serve as an example of the power of the computer and that others will accept the challenge of overcoming its limitations.
BIBLIOGRAPHY

Books


Periodicals


Atkinson, R.C. "Beverly, the Computer is a Tutor," Psychology Today, 1968d, pp. 36-59.


Monographs


Unpublished Works


Tests


Computer Programs


APPENDIX A

User's Guide for CAI Author Language

Source Listing of Program
This program is written in FORTRAN IV and requires a minimum of computer knowledge and experience on the part of the user.

Introduction

A lesson consists of a series of instructional units with each unit having the form shown on the next page in figure 1.

These instructional units may be presented to the student in a sequential manner or in an order determined in advance by the lesson designer.

A typical lesson could take the form shown in figure 2.

Typical Lesson

Figure 2

User's Guide for CAI Author Language
Student is asked a question

If the student responds, the answer is given.

If the answer is not recognized, it is marked as a nonmatch.

Comment is made.

If the student needs help, it is given.

If the student responds correctly, the lesson continues.

If the student responds incorrectly, feedback is given.

The process repeats for the next question.

* $Q_i$, $Q_j$, $Q_k$, $Q_m$, $Q_{j+1}$ represent different instructional units (IUs) in the lesson.

$\triangle$ means the $n$th time through the block.

Figure 1

Main Lesson Instructional Logic
Using the Program

Each instructional unit (Question) is coded in essentially the same manner as shown below.

CARD 1

Col. 1-2: Question number, right justified. Must be integer number between 1 and 30.

CARD 2

Col. 2: No. of response classes. Maximum is 4
Col. 4: No. of keywords in response class 1. Maximum is 8
Col. 6: No. of keywords in response class 2. Maximum is 8
Col. 8: No. of keywords in response class 3. Maximum is 8
Col. 10: No. of keywords in response class 4. Maximum is 8

CARD 3

Col. 1-80: Any comment that the lesson designer wishes to have the computer make to the student. This comment always begins the unit and will contain a question to the student. SIX cards maximum. Last card must contain a $END in col. 77-80.

CARD 4

Col. 1-80: Any comment that the lesson designer wishes to have the computer make to the student if the student asks for help. THREE cards maximum. Last card must contain a $END in col. 77-80.
CARD 5

Col. 1-10: The first keyword accepted as correct answer. Should begin in col. 1 and end with a $ sign.

Col. 11-20: The second keyword accepted as correct answer. Should begin in col. 11 and end with a $ sign.

Col. 21-30, 31-40, 41-50, 51-60, 61-70, 71-80: Other keywords accepted as correct answer. Should begin in appropriate column and end with a $ sign. The number of keywords on this card should be the same as the number indicated in col. 4 of card 2.

CARD 6

Col. 1-80: Any comment that the lesson designer wishes to have the computer make to the student if; (1) the student responds correctly, i.e. response wishes a keyword on last card, (2) the student asks for help more than once, (3) the student responds more than once to the same wrong answer class, (4) the student's response is not recognized more than twice. FIVE cards maximum. Last card must contain a $END in col. 77-80. This card may also be a GOTO command. See last section.

CARD 7

Col. 1-10: First keyword accepted as wrong answer. Should begin in col. 1 and end with a $ sign.

Col. 11-80: Same as on card 5. Other keywords accepted as wrong answer. Number of keywords on this card should be the same as the number indicated in col. 6 of card 2.
CARD 8

Col. 1-80: Any comment that the lesson designer wishes to have the computer make to the student if his response matches one of the keywords given on card 7. FIVE cards maximum. Last card must contain a $END in col. 77-80. This card may also be a GOTO command. See last section.

CARD 9
Same form as card 7

CARD 10
Same form as card 8

CARD 11
Same form as card 7

CARD 12
Same form as card 8

The total number of keyword cards (i.e. cards 5, 7, 9, 11) must be the same as the numbers in col. 2 of card 2. This number is limited to a minimum of one and a maximum of four.

Note: In order to construct a lesson having more than thirty instructional units, special techniques must be used. See the author for details.

GOTC Command

Branching to any point in the instructional lesson is possible by using a GOTO command. This command may replace any comment card (5) such as cards 6, 8, 10 or 12. If an instructional unit has been presented twice to the student, a GOTO command to that instructional unit will be ignored and the computer will proceed to the next question.
A GOTO command must begin in col. 1 and has the form GOTOXX where XX is the instructional unit number, right-justified, where the program will branch if that response class is chosen by the student.

System Commands

The Michigan Terminal System (MTS) is currently in use at the University of British Columbia. The user should create a desk file to store the instructional program, e.g. CAI. The CAI program may then be run by entering the following commands, starting in column 1:

$RUN CAI 5=LESSON 9=*MSOURCE
## Sample Question

**Question 1:**

What is $7 \times 8$?

This can be written as $7 \times 8$.

**Question 2:**

Today we're looking into multiplication.

Multiplication is just repeated addition. If we take the sum of 7 groups of 8 things, we can say we have $7 \times 8$ things.

**Question 3:**

What is $7 \times 8$?

This is written as $7 \times 8$.
IST - CAI

1  C  DAVID KAUFMAN  PROGRAM FOR MAIN CAI LESSON
2  C  THE MAIN PROGRAM READS THE QUESTION NUMBER (IQ), NUMBER OF RESPONSE
3  C  CLASSES (KC), NUMBER OF KEYWORDS IN EACH CLASS (KTOT), ALL KEYWORDS (KEY),
4  C  ALL QUESTIONS (QUS), HELP COMMENTS (QMOD), COMMENTS FOR EACH QUESTION (TEXT),
5  C  THE MAIN PROGRAM ALSO CONTROLS THE FLOW OF THE LESSON IN EITHER A
6  C  SEQUENTIAL OR NON-SEQUENTIAL MANNER AS SPECIFIED IN ADVANCE BY THE LESSON
7  C  DESIGNER. THE STATISTICS FOR EACH QUESTION IN THE LESSON, I.E., NUMERO
8  C  OF RESPOENSES MADE BY THE STUDENT IN EACH RESPONSE CLASS (RES) ARE WRITTEN
9  C  WHERE THE RESULTS MAY BE WRITTEN. RESPONSE LATENCIES ARE ALSO WRITTEN
10  C  FOR EACH RESPONSE ON EACH INSTRUCTIONAL UNIT.
11  C  A LESSON IS LIMITED TO 30 INSTRUCTIONAL UNITS
12  C  ANS (30,6), KEY (30,8,10)
13  C  QUS (30,120), QMOD (30,60), TEXT (10,4,100), STHO (30,6),
17 1 COUNT (30), CLASS (30)
18 DIMENSION NUM (30), KTOT (30, 4), NRES (3, 30, 6), NAME (30), LQ (30), LK (30),
19 1E (30, 4), SEC (30, 10)
20 COMMON TEXT, QUEST, QMOD, STNO, IP, IQ, NRES, COUNT, LQ, LK, N,
21 NAME, CLASS, KTOT, KEY, SEC, RES
22 DATA END, IB, IGO, SEND, ' ', ' ', ' ', 'GOTO', '
23 DATA NUM (1), NUM (2), NUM (3), NUM (4), NUM (5), NUM (6), NUM (7), NUM (8),
24 NUM (9), NUM (19), NUM (11), NUM (12), NUM (13), NUM (14), NUM (15), NUM (16),
25 NUM (17), NUM (18), NUM (19), NUM (20), '1', '2', '3', '4', '5', '6', '7', '8', '9', '10', '11', '12', '13', '
26 $14$, '15', '16', '17', '18', '19', '20', '
27 DATA NUM (21), NUM (22), NUM (23), NUM (24), NUM (25), NUM (26),
28 NUM (27), NUM (28), NUM (29), NUM (30), '21', '22', '23', '24', '25', '26', '27', '28', '29', '30', '
29 C INITIALIZE COUNTERS TO ZERO
30 IGE = 0
31 DO 41 I = 1, 30
32 COUNT (I) = 0
33 END
34 DO 41 J = 1, 6
35 DO 42 L = 1, 3
36 NRES (L, I, J) = 0
37 END
38 WRITE (6, 13)
39 FORMAT (' PLEASE ENTER YOUR FIRST AND LAST NAME')
40 DO 42 I = 1, 10
41 L1 = 1
42 L2 = 20
43 L3 = 1
44 L4 = 20
45 C READ NUMBER OF THE INSTRUCTIONAL UNIT BEING PREPARED
46 READ (5, 1, END = 20) IQ
47 1 FORMAT (I2)
48 C READ THE NO. OF RESPONSE CLASSES AND THE NO. OF KEYWORDS IN
49 EACH RESPONSE CLASS
50 READ (5, 2) KC, (KTOT (IQ, J), J = 1, KC)
51 2 FORMAT (10I2)
52 C READ THE QUESTION TO BE PRESENTED TO THE STUDENT
53 READ (5, 4) (QUEST (IQ, J), J = L1, L2)
54 3 FORMAT (5, 4) (QUEST (IQ, J), J = L1, L2)
55 C CHECK FOR THE END OF A COMMENT
56 IF (QUEST (IQ, L2). EQ. END) GO TO 5
57 C CHECK THAT THE INPUT IS CORRECT. IF NOT, GIVE ERROR MESSAGE TO AUTHOR
58 L1 = L1 + 20
59 L2 = L2 + 20
60 L3 = L3 + 20
61 IF (L1, L2, L2). EQ. SEND) GO TO 3
62 WRITE (6, 90) IQ
63 90 FORMAT (' TOO MANY CARDS OR NO SEND IN FIRST PART OF QUEST. NO.')
64 13)
65 STOP
66 13)
67 5 QUEST (IQ, L2) = IB
68 LQ (IQ) = L2
69 C READ IN HELP CONSENT
70 READ (5, 4) (QMOD (IQ, J), J = L3, L4)
71 11 FORMAT (20A4)
72 C CHECK THAT INPUT IS CORRECT. IF NOT, GIVE ERROR MESSAGE
73 IF (QMOD (IQ, L4). EQ. END) GO TO 12
74 L3 = L3 + 20
LH=LH+20
IF(L4.LT.60)GO TO 11
WRITE(6,91)IQ
91 FORMAT(' TOO MANY CARDS OR NO SEND IN A CORRECT OF QUES. NO.*',

STOP
12 QMOD(IQ,L4)=IB
LH(IQ)=L4
DO 66 H=1,KC
66 CONTINUE
M1=1
M2=20
C READ ALL KEYWORDS IN EACH RESPONSE CLASS
READ(5,6)((KEY(IQ,II,J,K),K=1,10),J=1,8)
6 FORMAT(80AS)
C READ COMMENTS TO BE GIVEN TO STUDENTS FOR EACH RESPONSE CLASS
8 READ(5,4)((TEXT(IQ,II,J),J=1,M2)
9 FORMAT(40AS)
C CHECK FOR A BRANCH TO ANOTHER INSTRUCTIONAL UNIT
IF(TEXT(IQ,II,1).NE.I00)GO TO 10
C CHECK THAT THE INPUT IS CORRECT, IF NOT,GIVE ERROR MESSAGE TO AUTHOR
DO 60 IK=1,30
60 IF (TEXT(IQ,11,2).EQ.NUM(IK)) GO TO 30
60 CONTINUE
WRITE (6,93) IQ
STOP
30_ ST10 CIQ,II) =IK
TEXT(IQ,II,1)=IE
106 TEXT(IQ,II,2)=IB
GO TO 66
C CHECK FOR THE END OF A COMMENT
10 IF (TEXT(IQ,II,M2).EQ.IEND) GO TO 9
10 CONTINUE
WRITE(6,91)IQ
STOP
9 TEXT(IQ,II,M2)=IE
K(IQ,II)=M2
66 CONTINUE
N=1
H2=M2*20
C KEEP COUNT ON THE NO. OF THE INSTRUCTIONAL UNIT BEING EXECUTED
COUNT(I)=COUNT(IN)+1
CALL Q(IN,OUT)
C WRITE RESPONSE LATENCIES ON A FILE
WRITE(4,155)IN,(SEC(IN,K),K=1,INRES)
155 FORMAT(25AS)
105 FORMAT(1H,15,10F8.1)
GO TO (50,70),II
70 IF(COUNT(IN,OUT).GE.2)OUT=IN+1
50 IF(INCOT.GT.NTOT)GO TO 55
IN=OUT
55 GO TO 33
C WRITE STUDENT NAME ON A FILE
WRITE(4,102)(NAME(I),I=1,10)
55 WRITE(4,102)(NAME(I),I=1,10)
C WRITE TABLE OF NUMBER OF RESPONSES IN EACH CLASS WITH HEADINGS ON FILE
WRITE(1,100)
137 100 FORMAT(' QUES',5X,'CLASSES',4X,'TIMES',5X,'HELP',2X,'CL ',
138 121,'CL2',2X,'CL3',2X,'CL4',2X,'NOMATCH'/)
139 DO 103 NQ=1,MTOT
140 KCO=COUNT(NQ)
141 KCL=CLASS(NQ)
142 103 BRITE(4,101) NQ,KCL,KCO,( (S3ES(L,NQ,J) ,J=1,MK),L=1,KCO)
143 101 FORM AT(4 X, 12.3(91,11), 4(X',11),6X', I1/(3 IX, 5(4X, 11) » 61, 11) )
144 STOP
145 END
146 C
147 C SUBROUTINE Q(NO,OUT)
148 C THIS SUBROUTINE CONTROLS THE PROCESSING FOR EACH INSTRUCTIONAL UNIT
149 C UNTIL THAT UNIT IS COMPLETED, CONTROL IS THEN RETURNED TO THE MAIN PROGRAM.
150 C THIS SUBROUTINE GIVES THE APPROPRIATE COMMENT TO THE STUDENT BASED ON THE
151 C RESPONSE CLASS INTO WHICH FELL HIS RESPONSE. COUNTERS FOR THE NUMBER OF.
152 C ERRORS ON EACH INSTRUCTIONAL UNIT ARE KEPT TRACK OF IN THIS SUBROUTINE.
153 C
154 C INTEGER*2 ANS(80),KEY(30,4,8,10)
155 INTEGER QUES(30,120),QMOD(30,6C),TEXT(30,100),STNO(30,6),
156 INTEGER QUES(30,120),QMOD(30,6C),TEXT(30,100),STNO(30,6),
157 IDNT(30),CLASS(30)
158 DIMENSION K(6),KTOT(30,4),NRES(3,30,6),LQ(30),LN(30),R(30,4)
159 C COMMON TEXT,QUES,QMOD,STNO,IP,IGX,NRES,COUNT,LO,LN,R
160 C 1,ANS,CLASS,KTOT,KEY,SEC,IRES
161 C INITIALIZE COUNTERS TO ZERO
162 C
163 IRES=0
164 K1=0
165 K2=0
166 K6=0
167 DO 77 L=3,5
168 77 K(L)=0
169 L2=LQ(NO)
170 C PRESENT THE QUESTION TO THE STUDENT
171 WRITE(6,1)(QUES(NO,1),J=1,L2)
172 C KEEP A TIMER FOR RESPONSE LATECY
173 3 CALL TIME(0)
174 C READ-IN STUDENT RESPONSE.FIRST 40 CHARACTERS ARE READ
175 READ(9,2)(ANS(I),I=1,40)
176 CALL TIME(2,6,NLAT)
177 IRES=IRES+1
178 SEC(NO,IRES)=NLAT/1000.
179 CALL MATCH(NO,KQ)
180 C KEEP A COUNTER FOR THE NUMBER OF ERRORS IN EACH RESPONSE CLASS
181 NRES(COUNT(NO),NO,NEXT)=NRES(COUNT(NO),NO,NEXT)+1
182 GO TO (10,20,30,30,98),NEXT
183 C NEXT SECTION
184 10 K1=K1+1
185 IF(K1.EQ.2)GO TO 99
186 2=LN(NO)
187 WRITE(6,1)(QMOD(NO,1),J=1,4)
188 GO TO 3
189 C CORRECT RESPONSE SECTION
190 20 K2=K2+1
191 12 IOUT=KQ+1
192 IF(IGX.EQ.0)WRITE(6,21)
193 IF(IGX.EQ.1)WRITE(6,22)
194 IF(IGX.EQ.2)WRITE(6,23)
195 IF(IGX.EQ.3)WRITE(6,24)
196 IGX=IGX+1
197 IF (STNO(NO, NEXT-1) . EQ. 0) GO TO 99
198 IOUT=STNO(NO, NEXT-1)
199 IP=2
200 RETURN
201 C WRONG ANSWER SECTION
202 30 K(NEXT) = K(NEXT)+1
203 IF (STNO(NO, NEXT-1) . EQ. 0) GO TO 13
204 IOUT=STNO(NO, NEXT-1)
205 IP=2
206 RETURN
207 13 IOUT=NO+1
208 IF (K(NEXT) . EQ. 2) GO TO 99
209 NN=NEXT-1
210 NN=K(NO, NN)
211 WRITE(6,1) (TEXT(NO, NN), J=1, NN)
212 GO TO 97
213 C NOMATCH SECTION
214 98 K6=K6+1
215 IF (K6 . EQ. 1) WRITE(6,92)
216 IF (K6 . EQ. 2) WRITE(6,93)
217 IF (K6 . EQ. 3) GO TO 99
218 97 IGX=0
219 GO TO 3
220 99 IOUT=NO+1
221 WRITE(6,1) (TEXT(NO, J), J=1, NO)
222 RETURN
223 FORMAT(•/ , (1H , 20A4))
224 FORMAT((80A1))
225 21 FORMAT(' OK! ')
226 22 FORMAT(' GOOD! ')
227 23 FORMAT(' EXCELLENT! ')
228 24 FORMAT(' EXCELLENT! KEEP UP THE GOOD WORK. ')
229 92 FORMAT(' I DON'T RECOGNIZE YOUR RESPONSE. TRY AGAIN! ')
230 93 FORMAT(' BE CAREFUL. I STILL DON'T READ YOUR ANSWER AGAIN! ')
231 94 FORMAT(' I DON'T RECOGNIZE YOUR RESPONSE. TRY AGAIN! ')
232 END
233 C
234 C SUBROUTINE MATCH(NO, NEXT)
235 C SUBROUTINE TO MATCH STUDENT'S RESPONSE TO KEYWORD
236 C THIS SUBROUTINE IS A CHARACTER MATCHING ROUTINE THAT LOOKS FOR A MATCH OF
237 C THE STUDENT'S RESPONSE WITH ANY OF THE KEYWORDS, WITH A BLANK RESPONSE OR
238 C WITH THE WORD HELP. THIS ROUTINE RETURNS THE VALUE OF THE RESPONSE CLASS
239 C THAT THE STUDENT HAS HIT WITH HIS RESPONSE TO THE SUBROUTINE Q.
240 C
241 C INTEGER AS(30), KEY(30,4,8,10), IB, IF1W, II,12,13,14
242 C INTEGER QUES(30,120), Q Question(30,60), TEXT(30,4,100), STNO(30,60),
243 C COUNT(30), CLASS(30)
244 C DIMENSION KOT(30,4), KRES(3,3C,6), Q(70), LM(30), K(30,4)
245 C INK(30,10)
246 COMMON TEXT, QUES, QuesEnd, IP, IGX, HR, COUNT, LM, K
247 C DATA IB, IF1W, II,12,13,14, 'H', 'R', 'E', 'L', 'P'/
248 C INITIALIZE COUNTERS
249 C K=1
250 C L=1
251 C LL=1
252 C
C CHECK FOR HELP RESPONSE
       IF (ANS (1). NE. 11) GO TO 3
       IF (ANS (1*1). EQ. 12. AND. ANS (1*2). EQ. 13. AND. ANS (1*3). EQ. 14) GO TO 10
       DO 30 I=1,40

C CHECK FOR BLANK RESPONSE
       IF (ANS (1) . LE. 11) GO TO 22

C CHECK FOR END OF KEYWORD ($) 

C ONLY FIRST 40 CHARACTERS OF RESPONSE ARE CHECKED
       LL=1
       IF (L.GT.40) GO TO 5

C CHECK IF ALL LETTERS IN RESPONSE HAVE BEEN MATCHED
       IF (L.LE.MAX) GO TO 2
       LL=L+1

C CHECK THAT ALL KEYWORDS IN THAT CLASS HAVE BEEN LOOKED AT
       IF (K.LE.KTOT (NQ,KLASS)) GO TO 22
       L=1

C NEXT IS THE VALUE OF THE RESPONSE CLASS WHERE STUDENT'S RESPONSE FELL. RETURN THIS VALUE TO SUBROUTINE Q.
       NEXT=1
       RETURN
       NEXT=6
       RETURN
       NEXT=KLIASS+1
       RETURN

D C* FILE
APPENDIX B

User's Guide for Prelesson Author Program

Source Listing of Program
Question is asked

Can student answer on first try?

yes → *Mark = 2

Next question is asked

no → Assistance is given to student

Student is asked to answer once again

Question is asked similar to above

Mark = 0

Can student answer on first try?

no → $Q_{i+1}$

yes → Mark = 1

$Q_{i+1}$

* Mark refers to the grade assigned to the student for a particular instructional unit, or item, $Q_i$.

Figure 1

Prelesson Instructional Logic
Description of CAIPRE, Pretest Program

This program is essentially the same as the program for the main lesson (CAIPRE). The statistics section has been removed.

Modifications have been made so that the program follows the logic of the pretest - template. Precautions have been taken to insure that the student cannot "sneak" through a question, in fact, he may be caught in a loop if he refuses to follow the instructions given to him.

The logic is changed so that all NOMATCH answers are channelied to the first wrong answer class. This means that comments which the student receives if his answer matches a key word in the first wrong answer class will also be given if his answer is not recognized.

The logic used here allows for easier coding of lessons. It is usual to use only two answer classes, a correct class with all acceptable keywords and a wrong class with one keyword is only required since NOMATCH answers go to this class anyway. See figure 1.
C DAVID KAUFMAN__ PROGRAM TO RUN PRETEST LESSON

C MAIN PROGRAM DETERMINES BRANCHING LOGIC

INTEGER*2 ANS(80),KEY(30,4,8,10)
INTEGER QUES(30,120),QMOD(30,60),TEIT(30,4,100),STNO(30,6),
COUNT(30),CLASS(30)
DIMENSION NUM(30),KTOT(30,4),RES(3,30,6),NAME(30),LQ(30),LM(30),
TEXT(30,10),QMOD(30,10)
COMMON TEXT,QUES,QMOD,STNO,IP,TEX,RES,COUNT,LQ,LM,M

DATA IEND,IB,IGO/*SEND*/,' ','GOTO*/
DATA NUM(1),SUB(2),NUM(3),NUM(4),NUM(5),NUM(6),NUM(7),NUM(8),
NUM(9),NUM(10),NUM(11),NUM(12),NUM(13),NUM(14),NUM(15),NUM(16),
NUM(17),NUM(18),NUM(19),NUM(20),/ 1 ,/ 2 ,/ 3 ,/ 4 ,
NUM(21),NUM(22),NUM(23),NUM(24),NUM(25),NUM(26),NUM(27),
NUM(28),NUM(29),NUM(30),/ 21 ,/ 22 ,/ 23 ,/ 24 ,/ 25 ,
IB=0
1 COUNT(I)=0
2 DO 41 J=1,30
3 41 ANS(J)=0
4 DO 42 L=1,3
5 42 NUM(L,J)=0
6 WRITE(6,13)

13 FORMAT('PLEASE ENTER YOUR FIRST AND LAST NAME')
7 READ(2,19)NAME(1),I=1,10
8 19 FORMAT(10A4)
9 DO 33 I=1,31
10 L=1
11 33 L=L+20
READ(5,1,END=20)IQ
1 FORMAT(12)
READ(5,2)KC, (KTOT(IQ,J),J=1,KC)
CLASS(IQ)=KC
2 FORMAT(9I2)
3 READ(5,4) (QUES(IQ,J),J=L1,L2)
4 FORMAT(20A4)
IF(QUES(IQ,L2),EQ.IEND)GO TO 5
L1=L1+20
L2=L2+20
IF(L2.LE.120)GO TO 3
WHITE(6,90)IQ
90 FORMAT(80A2)
STOP
5 QUES(IQ,L2)=IB
LQ(IQ)=L2
11 READ(5,4) (QMOD(IQ,J),J=L3,L4)
L3=L3+20
L4=L4+20
IF(L4.LE.60)GO TO 11
WRITE(6,91)IQ
91 FORMAT(' TOO MANY CARDS OR NO SEND IN FIRST PART OF QUES. NO.'),
STOP
12 QMOD(IQ,L4)=IB
LH(IQ)=L4
DO 66 II=1,KC
66 READ(5,6) ((KEY(IQ,II,K),K=1,10),J=1,8)
6 FORMAT(80A1)
8 READ(5,4) (TEXT(IQ,II,J),J=M1,M2)
7 IF(TEXT(IQ,II,1),.NE.IGO)GO TO 10
DO 60 IX=1,30
70 IF(TEXT(IQ,II,2),EQ.NUM(IX))GO TO 30
60 CONTINUE
WRITE(6,93)IQ
93 FORMAT(' INCORRECT GOTO STATEMENT IN CLASS',13,2X),
1 QUESTION NO.'),13)
STOP
30 STRW(IQ,T7)=IX
10 TEXT(IQ,II,1)=IB
81 TEXT(IQ,II,2)=IB
GO TO 66
10 IF(TEXT(IQ,II,M2),EQ.IEND)GO TO 9
M1=M1+20
M2=M2+20
IF(M2.LE.100)GO TO 9
WRITE(6,91)IQ
STOP
9 TEXT(IQ,II,2)=IB
90 M(IQ,II)=M2
C6 CONTINUE
33 CONTINUE
93 20 ETOT=IN-1
IN=1
175

COUNT(IN) = COUNT(IN) + 1
CALL Q(IN, IOUT)

WRITE(6, 18) IN, (SEC(IN, J), J = 1, IRES)
FORMAT(18, I5, 10F8.1)
IF (IOUT.GT. HTOT) GO TO 55
IN = IOUT
GO TO 43
55 CONTINUE
STOP
END

SUBROUTINE Q(NO, IOUT)
INTEGER#2 ANS(80), KEY(30, 4, 8, 10)
INTEGER QUES(30, 120), QMOD(30, 60), TEXT(30, 4, 100), STNO(30, 6),
COUNT(30), CLASS(30)
DIMENSION K(6), KTOT(30, 4), NRES(3, 30, 6), LQ(30), LB(30), H(30), M(30, 4)
SEC(30, 10)
COMMON TEXT, QUES, QMOD, STNO, IF, IGX, NRES, COUNT, LQ, LB, H
IRES = 0
K1 = 0
K2 = 0
K6 = 0
KANS = 0
DO 77 L = 3, 5

K(L) = 0
L2 = LO(NO)
WRITE(6, 1) (QUES(NO, I), I = 1, L2)
3 CALL TIME() READ(9, 2) (ANS(I), I = 1, 90)
CALL TIME(2, 0, X, T2)
IRES = IRES + 1
SEC(NO, IRES) = XLAT/1000.
CALL PATCH(NO, NEXT)
WHERE(COUNT(NO), NO, NEXT) = NRES(COUNT(NO), NO, NEXT) + 1
GO TO (10, 20, 30, 30, 98), NEXT
10 K1 = K1 + 1
11 IF(K1.EQ.2) GO TO 99
12 L4 = LE(NO)
WHITE(6, 1) (QMOD(NO, I), I = 1, L4)
GO TO 3
20 K2 = K2 + 1

12 IOUT = NO + 1
IF (IGX.EQ.0) WRITE(6, 21)
IF (IGX.EQ.1) WRITE(6, 22)
IF (IGX.EQ.2) WRITE(6, 23)
IGX = IGX + 1
IF (IGX.EQ.3) GO TO 99
IF (STNO(NO, NEXT - 1).EQ.0) GO TO 99
IOUT = STNO(NO, NEXT - 1)
RETURN
156 \textbf{30} K(NEXT) = K(\text{\textit{NEXT}}) + 1
157 KANS = KANS + 1
158 IF(STNO(NQ, NEX-1) . EQ. 0) GO TO 13
159 IOUT = STNO(NQ, NEX-1)
160 IP = 2
161 RETURN
162 \textbf{13} IOUT = NQ + 1
163 IF(K(NEXT) . EQ. 2) GO TO 999
164 NN = NEX-1
165 MM = M(NQ, NM)
166 WRITE(6,1) (TEXT(NQ, NM, J), J = 1, NM)
167 GO TO 97
168 K6 = K6 + 1
169 IF(K6 . EQ. 1) WRITE(6,92)
170 IF(K6 . EQ. 2) WRITE(6,93)
171 IF(K6 . EQ. 3) GO TO 99
172 IGX = 0
173 GO TO 3
174 \textbf{99} N1 = M(NQ, 1)
175 IOUT = NQ + 1
176 WRITE(6,1) (TEXT(NQ, 1, J), J = 1, N1)
177 IP = 1
178 RETURN
179 \textbf{999} IOUT = NQ + 1
180 RETURN
181 \textbf{1} FORMAT(*/, (1H, '204))
182 \textbf{2} FORMAT(*OA)1)
183 \textbf{21} FORMAT(*OK*)
184 \textbf{22} FORMAT(*GOOD*)
185 \textbf{23} FORMAT(*EXCELLENT*)
186 \textbf{24} FORMAT(*EXCELLENT! KEEP UP THE GOOD WORK*)
187 \textbf{92} FORMAT(*I DON'T RECOGNIZE YOUR RESPONSE. TRY AGAIN*)
188 \textbf{C} \textbf{93} FORMAT(*BE CAREFUL. I STILL DON'T READ YOUR ANSWER AGAIN*)
189 END
190 SUBROUTINE MATCH(NQ, NEX)
191 INTEGER*2 AHS(80), KEY(30, 4, 8, 10), IB, IFIN, I1, I2, I3, I6
192 INTEGER QUES(30, 120), QMOD(30, 60), TEXT(30, 4, 100), STNO(30, 6),
193 QOUT(30), CLASS(30)
194 DIMENSION KTOT(30, 4), NRES(3, 30, 6), LQ(30), LN(30), N(30, 4)
195 \textbf{1} SEC(30, 10)
196 COMMON TEXT, QUES, QMOD, STNO, IP, IGX, NRES, COQT, LQ, LN, N
197 A, B, C, D, E, F, G, H, I, J, K, L
198 DATA IB, IFIN, I1, I2, I3, I4, I5 '*, ''*, 'H', 'I', 'J', 'K'
199 \textbf{200} DATA IB, IFIN, I1, I2, I3, I4, I5 '*, 'H', 'I', 'J', 'K', 'L'
201 KCLASS = 1
202 K = 1
203 I1 = 1
204 I2 = 1
205 I3 = 1
206 \textbf{1} IF(ABS(I) . NE. I1) GO TO 3
207 IF(ABS(I+1) . EQ. 12 AND. AHS(I+2) . EQ. 13 AND. AHS(I+3) . EQ. 14) GO TO 10
208 I = I + 1
209 I = I + 1
210 \textbf{3} CONTINUE
211 \textbf{10} I = I + 1
212 \textbf{3} \textbf{CONTINUE}
213 GO TO 10
214 \textbf{?2} WMA = 0
DO 20 L=1, 10
  RCH = NCHA + 1
  IF (KEY (NQ, KLA, S, K, IL).EQ. IFIN) GO TO 21
  CONTINUE
  IF (NQ .GT. 10) GO TO 5
  IF (ANS (L-1).EQ. IB) GO TO 2
  GO TO 20
  2  
  BAX = NCHA - 1
  IF (KEY (NQ, KLA, S, K, LL).EQ. ANS (L)) GO TO 4
  4  L = L + 1
  LL = 1
  IF (L .GT. 10) GO TO 5
  IF (ANS (L-1).EQ. IB) GO TO 2
  GO TO 20
  5  L = 1
  LL = 1
  K+1
  IF (K .LE. KTOT (NQ, KLA)) GO TO 22
  L = 1
  LL = 1
  K = 1
  KLA = KLA + 1
  IF (KLA .LE. CLASS (NQ)) GO TO 22
  GO TO 11
  10  NEXT = 1
  RETURN
  11  NEXT = 3
  RETURN
  12  NEXT = KLA + 1
  RETURN
  END

END OF FILE

$DES BIBLIO

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APPENDIX C

CAI Prelesson Listing
SHEET B

\[ S \]

\[ T \]

\[ \Delta L(s) \]

\[ \Delta L(t) \]
Hi, I'm your personal tutor for today. Let's start by doing a lesson on some of the things that you should know before doing the main lesson....

Look at the graph shown in sheet A.

What is the value of y at the point x=1?

Read the value off the graph.

No. Find the point on the curve which corresponds to a value of x=1.

By drawing a vertical line up from x=1 until it meets the curve, then draw a horizontal line to the left from that point until it meets the y-axis at one point. What is the value of y at that point?

You should use numerals instead of letters to represent numbers.

Please enter this number again correctly.

Suppose that you are told that s is a function of t.

What is the value of s when t=3, if s and t are related by the equation?

Read this as .... two times (t squared).
183

EIGHTEEN

GOTO 5

23 45

12

8

9

16

20

NO. YOU SHOULD SUBSTITUTE THE VALUE OF T, WHICH IS 3, INTO THE EQUATION

AND OBTAIN

S = 27*2 = 2(3) * 2 = 2(9) = ?

WHAT IS THE VALUE OF S WHEN T = 3?

GOTO 5

2

7

HOW SUPPOSE THAT WE ARE GIVEN THE EQUATION S = 3T*2, READ AS 3 TIMES T SQUARED.

WHAT IS THE VALUE OF S WHEN T = 2?

SUBSTITUTE THE VALUE OF T = 2 INTO THE EQUATION.

125

TWEELS

GOTO 5

3

6

9

15

27

18

WHAT IS THE VALUE OF S WHEN T = 2?

SUBSTITUTE THE VALUE OF T = 2 INTO THE EQUATION.

WHAT IS THE DISTANCE WHEN T = 3?

WHAT IS THE DISTANCE WHEN T = 2?

WHAT IS THE DISTANCE WHEN T = 3?

WHAT IS THE DISTANCE WHEN T = 2?

WHAT IS THE DISTANCE WHEN T = 3?

SUBSTITUTE THE VALUE OF T = 2 INTO THE EQUATION.

WHAT IS THE DISTANCE WHEN T = 3?

WHAT IS THE DISTANCE WHEN T = 2?

SUBSTITUTE THE VALUE OF T = 2 INTO THE EQUATION.

WHAT IS THE DISTANCE WHEN T = 3?

WHAT IS THE DISTANCE WHEN T = 2?

SUBSTITUTE THE VALUE OF T = 2 INTO THE EQUATION.

WHAT IS THE DISTANCE WHEN T = 3?

WHAT IS THE DISTANCE WHEN T = 2?

SUBSTITUTE THE VALUE OF T = 2 INTO THE EQUATION.
SOPPOSE THAT A CAR TRAVELS FROM MONTREAL TO TORONTO, A DISTANCE OF 350 MILES, AND THE DRIVER STOPS SEVERAL TIMES FOR FOOD AND GAS. What speed must the car average in order to make the trip in 7 hours? Since distance = (speed) (time), what is this average speed? 

No. The car stopped several times and did not keep a constant speed. The average speed is the speed at which the car would have to travel in order to travel 350 miles in seven hours. Average speed = distance/time = 350/7 = ?

During its journey, the same car passed KINGSTON, a distance of 160 miles from Montreal, after 4 hours. What speed did the car average? Distance = (speed) (time). What is this average speed?

SOPPOSE THAT ANOTHER CAR TRAVELLING FROM MONTREAL TO TORONTO (350 MILES) MOVES AT 70 MILES/HOUR FOR THE FIRST 3 HOURS AND AT 60 MILES/HOUR FOR THE NEXT 4 HOURS. What is the speed of this car exactly 50 minutes after leaving Montreal? The instantaneous speed. Is it moving exactly 50 minutes after leaving Montreal? The Instantaneous speed at a particular time is called. The car is travelling at 70 miles/hour for the first 3 hours. How fast is it going exactly 50 minutes after leaving Montreal? The Instantaneous speed is the speed at a particular time. What is the instantaneous speed? Let's take a short break from the lesson. I'd like to know how you feel...
1. A NOT AT ALL C MODERATELY SO
2. B SOMEWHAT D VERY MUCH SO
3. PLEASE ANSWER A,B,C,OR D.
4. ANSWER A,B,C,OR D TO DESCRIBE YOUR REACTION RIGHT NOW TO THE STATEMENT...
5. I AM TENSE.
6. PLEASE ANSWER A,B,C,OR D.
7. ANSWER A,B,C,OR D TO DESCRIBE YOUR REACTION TO THE STATEMENT...
8. I FEEL AT EASE.
9. PLEASE ANSWER A,B,C,OR D.
10. ANSWER A,B,C,OR D TO DESCRIBE YOUR REACTION TO THE STATEMENT...
11. I FEEL CALM.
12. PLEASE ANSWER A,B,C,OR D.
13. ANSWER A,B,C,OR D TO THE STATEMENT... I AM JITTERY.
14. I AM RELAXED.
15. PLEASE ANSWER A,B,C,OR D.
16. ANSWER A,B,C,OR D TO THE STATEMENT... I FEEL CALM.
17. PLEASE ANSWER A,B,C,OR D.
18. ANSWER A,B,C,OR D TO THE STATEMENT... I AM JITTERY.

NOW, LET'S GET BACK TO THE LESSON...
LOOK AT THE GRAPH OF S VS. T SHOWN IN SHEET B.
WHAT IS THE SLOPE OF THE LINE INDICATED ON THE GRAPH?
SLOPE IS JUST THE CHANGE IN S DIVIDED BY THE CHANGE IN T.
USING THE NOTATION THAT WE DEFINED EARLIER, SLOPE = ΔS/ΔT.
PICK TWO POINTS ON THE LINE AND CALCULATE THE SLOPE.

\[ \text{SLOPE} = \frac{\text{CHANGE IN DISTANCE}}{\text{CHANGE IN TIME}} \]

\[ \frac{\Delta S}{\Delta T} \]

WHAT IS THE SLOPE?

GOTO 20

20

WHAT IS THE SLOPE?

20

LOOK AT THE GRAPH OF \( S \) VS. \( T \) SHOWN IN SHEET C.

WHAT IS THE SLOPE OF THE LINE INDICATED ON THE GRAPH?

USING OUR NOTATION, \( \text{SLOPE} = \frac{\Delta S}{\Delta T} \) BETWEEN TWO POINTS ON THE LINE.

CALCULATE THIS SLOPE.

5

FIVE \( \frac{10}{2} \), \( \frac{20}{4} \), \( \frac{30}{6} \), \( \frac{40}{8} \).

GOTO 20

20

LET'S REVIEW SOME BASIC ALGEBRA. SAY THAT YOU ARE GIVEN THE EXPRESSION

\[ 3(1+X) \cdot 2 - 3(1) \cdot 2 / (1+X) - 1 \]

WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?

EXPAND \( 3(1+X) \cdot 2 \) IN THE NUMERATOR AND THEN SIMPLIFY THE NUMERATOR.

THE DENOMINATOR BECOMES \( (1+X) - 1 = X \).

WHAT IS THE FINAL FORM OF THE EXPRESSION?

THE NUMERATOR BECOMES \( 3(1+X) \cdot 2 - 3(1) \cdot 2 = 3(1+2X+X^2) - 3 \)

\[ = 6X + 3X^2 \cdot X \cdot (6+3X) \]

THE DENOMINATOR BECOMES \( (1+X) - 1 = X \).

WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?

WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?

Simplify exactly as above.

THE NUMERATOR BECOMES \( 3(1+DEL(T)) \cdot 2 - 3(1) \cdot 2 / (1+DEL(T)) - 1 \).

WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?

LOOK AT THE PREVIOUS PROBLEM. THE PROCEDURE IS THE SAME AS BEFORE.

EXCEPT THAT WE NOW HAVE USED \( \Delta T \) IN PLACE OF \( X \).

THE NUMERATOR BECOMES \( 3(1+DEL(T)) \cdot 2 - 3(1) \cdot 2 / (1+DEL(T)) - 1 \).

THE NUMERATOR BECOMES \( 3(1+DEL(T)) \cdot 2 - 3(1) \cdot 2 / (1+DEL(T)) - 1 \).

THE DENOMINATOR BECOMES \( (1+DEL(T)) - 1 = DEL(T) \).

\[ \Delta S \]

\[ \Delta T \]

\[ \frac{\Delta S}{\Delta T} \]

\[ \text{SLOPE} = \frac{\text{CHANGE IN DISTANCE}}{\text{CHANGE IN TIME}} \]

\[ \frac{\Delta S}{\Delta T} \]

\[ \text{SLOPE} = \frac{\text{CHANGE IN DISTANCE}}{\text{CHANGE IN TIME}} \]

\[ \frac{\Delta S}{\Delta T} \]
THEN THE EXPRESSION BECOMES \( \frac{6 + 3 \text{DEL}(T)}{\text{DEL}(T)} = \text{???} \)

NOW, YOU ARE GIVEN AN EXPRESSION

\( (2 \cdot \text{DEL}(T)) \cdot 2 - 2 \cdot 2 / (2 \cdot \text{DEL}(T)) - 2 \)

WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?  

PROCEED EXACTLY AS BEFORE.  

\( 4 \cdot \text{DEL}(T) + 4 \cdot \text{DEL}(T) = \text{???} \)

\( \text{GOTO24} \)

\( 2 \cdot 2 \)

\( / \$

\( \text{GOTO24} \)

\( 2 \cdot 2 \)

YOU SEEM TO UNDERSTAND THE CONCEPTS NEEDED TO TAKE THE MAIN LESSON.

YOU MAY TAKE A SHORT BREAK OR YOU CAN START THE MAIN LESSON

RIGHT AWAY.  
DO YOU WANT TO TAKE A BREAK?  

\( \text{NO} \) OR \( \text{YES} \).

\( \text{NO} \)

\( \text{OK} \)

\( \text{YES} \)

\( \text{OK} \)

\( \text{THEN TAKE A SHORT REST AND WHEN YOU'RE READY, TYPE...SOURCE LESSON} \)

FILE
APPENDIX D

CAI Main Lesson Listing

(versions $T_1$, $T_2$, $T_3$)
SHEET 1

GRAPH OF DISTANCE VS. TIME FOR FIRST BOAT

DISTANCE $S$ (miles)

TIME $T$ (hours)
GRAPH OF DISTANCE VS. TIME FOR SECOND BOAT

DISTANCE $S$ (miles)

TIME $T$ (hours)
SHEET 3

GRAPH OF DISTANCE VS. TIME FOR SECOND BOAT

DISTANCE $S$ (miles)

TIME $T$ (hours)
SHEET 4

GRAPH OF DISTANCE VS. TIME

DISTANCE S
(feet)

TIME T
(seconds)
Note: \( \Delta t = \Delta (T) \)

Time

\( \Delta t \)

\( \Delta x \)

\( s = 3 \Delta x \)

Graph of \( s = 3 \Delta x \)

Sheet 5

193
LET'S STUDY THE MOTION OF A BOAT AS IT LEAVES A DOCK.

SOPPOSE THAT IT'S MOVING AT A CONSTANT SPEED OF 10 MILES/HOUR.

WHAT IS THE DISTANCE S OF THE BOAT FROM THE DOCK AT ANY TIME T?

REMEMBER THAT DISTANCE = SPEED * TIME. WRITE AN EQUATION FOR S IN TERMS OF T.

THE EQUATION WHICH DESCRIBES THE MOTION OF THE BOAT IS S = 10T.

 THIS IS SIMPLY THE FAMILIAR DISTANCE = (SPEED) * (TIME) EQUATION, WITH SPEED V BEING CONSTANT AT 10 MILES/HOUR.

THIS IS THE EQUATION RELATING DISTANCE, SPEED, AND TIME. NOW REARANGE IT TO GET DISTANCE S ALONE ON THE LEFT HAND SIDE.

THIS IS PART OF THE ANSWER. REMEMBER THAT DISTANCE = (SPEED) * (TIME) AND YOU HAVE ONLY LOOKED AT ONE OF THESE QUANTITIES. TRY AGAIN.

THE DISTANCE S GIVEN BY S = 10T. WHAT IS THE EQUATION FOR S IN TERMS OF T?
1. **LOOK AT SHEET 1 THAT WAS GIVEN TO YOU.**
2. **THE GRAPH INDICATES HOW FAR THIS BOAT IS FROM THE DOCK AT ANY TIME.**
3. **WHAT IS THE SLOPE OF THIS STRAIGHT LINE REPRESENTING THE BOAT'S MOTION IN A TIME INTERVAL \( T=2 \) TO \( T=6 \) HOURS?**
4. **YOU NEED TO OBTAIN THE CHANGE IN DISTANCE AND THE CHANGE IN TIME BETWEEN THESE TWO POINTS IN ORDER TO CALCULATE THE SLOPE. GO AHEAD...**
5. **THE SLOPE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME.**
6. **WE WRITE THIS AS \( \text{slope} = \frac{\Delta s}{\Delta t} \), which is equal to \( \frac{50-20}{6-2} = \frac{30}{4} = 7.5 \) MILES/HOUR.**
7. **ALMOST RIGHT.**
8. **YOU'VE CALCULATED THE CHANGE IN DISTANCE AND THE CHANGE IN TIME CORRECTLY, BUT YOU'VE DIVIDED THEM INCORRECTLY.**
9. **THE SLOPE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME. TRY AGAIN.**

---

11. **WHAT IS THE SLOPE OF THE LINE IN THE TIME INTERVAL \( T=4 \) TO \( T=8 \) HOURS?**
12. **YOU NEED TO OBTAIN THE CHANGE IN DISTANCE AND THE CHANGE IN TIME BETWEEN THESE TWO POINTS IN ORDER TO CALCULATE THE SLOPE. GO AHEAD...**
13. **THE SLOPE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME. TRY AGAIN.**
14. **THE SLOPE IS \( \frac{\Delta s}{\Delta t} = \frac{60-20}{8-4} = \frac{40}{4} = 10 \) MILES/HOUR. THIS IS ALWAYS THE CASE WHEN THE GRAPH OF THE MOTION IS A STRAIGHT LINE. THE GRAPH IS JUST A PICTURE OF THE EQUATION OF MOTION \( s = 10t \), AND SO THE SLOPE OF THE LINE IS THE SPEED OF THE BOAT.**

---

15. **SHEET 2 ILLUSTRATES THE MOTION OF A SECOND BOAT.**
16. **COMPUTE THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL FROM \( T=2 \) TO \( T=6 \) HRS.**
17. **PROCEED EXACTLY AS BEFORE.**
18. **THE AVERAGE SPEED IS SIMPLY THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME: \( \text{average speed} = \frac{\Delta s}{\Delta t} \).**
19. **CHARGE IF THIS IS GIVEN: \( \frac{\Delta s}{\Delta t} = \frac{60-20}{8-4} = \frac{40}{4} = 10 \) MILES/HOUR.**
20. **ALMOST RIGHT.**
21. **YOU HAVE DIVIDED DISTANCE BY TIME, BUT YOU HAVE ONLY CONSIDERED ONE END OF THE INTERVAL FROM \( T=2 \) TO \( T=6 \).**
22. **CALCULATE THE CHANGE IN DISTANCE AND DIVIDE BY THE CHANGE IN TIME.**
11 TO GET AVERAGE SPEED.
12
13 NO. THIS IS THE VALUE OF A COORDINATE AT ONE END OF THE INTERVAL.
14 THE AVERAGE SPEED IS GIVEN BY CHANGE IN DISTANCE,
15 \( \Delta S \), DIVIDED BY CHANGE IN TIME, \( \Delta T \), FROM P TO Q. CALCULATE
16 THIS FROM THE GRAPH.
17
18 INCORRECT. YOU'VE CALCULATED THE CHANGE ON ONLY ONE AXIS OF THE GRAPH. THE
19 AVERAGE SPEED IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME
20 FROM T=2 TO T=6. CALCULATE THIS FROM THE GRAPH...
21
22 4 1 3 2
23
24 LOOK AT SHEET 3, WHICH IS JUST THE GRAPH IN SHEET 2 WITH THREE POINTS
25 P, Q, AND R INDICATED ON IT.
26 WHAT IS THE SLOPE OF THE LINE SEGMENT JOINING THE POINTS P AND Q?
27 YOU NEED TO KNOW THE CHANGE IN DISTANCE AND THE CHANGE IN TIME BETWEEN
28 P AND Q IN ORDER TO CALCULATE THE SLOPE OF THE LINE SEGMENT. GO AHEAD...
29
30 THE SLOPE OF THE LINE SEGMENT JOINING P AND Q IS GIVEN BY CHANGE IN
31 DISTANCE DIVIDED BY CHANGE IN TIME, WHICH IS \( \Delta S / \Delta T = 8/4 = 2 \text{ M/HR} \).
31 THIS IS THE SAME AS THE AVERAGE SPEED OF THE BOAT BETWEEN P AND Q.
32
33 ALMOST RIGHT SINCE YOU'VE DIVIDED DISTANCE BY TIME. BUT YOU HAVE ONLY
34 CONSIDERED ONE END OF THE INTERVAL FROM P TO Q. CALCULATE THE CHANGE
35 IN DISTANCE AND DIVIDE BY THE CHANGE IN TIME FROM P TO Q TO GET THE SLOPE.
36
37 INCORRECT. THIS IS THE VALUE OF A COORDINATE AT ONE END OF THE INTERVAL.
38 THE SLOPE OF THE LINE JOINING P AND Q IS GIVEN BY CHANGE IN DISTANCE,
39 \( \Delta S \), DIVIDED BY CHANGE IN TIME, \( \Delta T \), FROM P TO Q. CALCULATE
40 THIS FROM THE GRAPH...
41
42 INCORRECT. YOU'VE CALCULATED THE CHANGE ON ONLY ONE AXIS OF THE GRAPH. THE SLOPE
43 OF THE LINE JOINING P AND Q IS GIVEN BY CHANGE IN DISTANCE, \( \Delta S \),
44 DIVIDED BY CHANGE IN TIME, \( \Delta T \), FROM P TO Q. CALCULATE THIS FROM
45 THE GRAPH...
46
47 4 8 5 2 1
48 LET'S TAKE A SMALLER SIZE INTERVAL THAN BEFORE ON THE GRAPH IN SHEET 3.
49 WHAT IS THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL T=2 TO T=4 HOURS?
50 PROCEED EXACTLY AS BEFORE.
51
52 INCORRECT. THIS IS THE VALUE OF A COORDINATE AT ONE END OF THE INTERVAL.
53 THE SLOPE OF THE LINE JOINING P AND Q IS GIVEN BY CHANGE IN DISTANCE,
54 \( \Delta S \), DIVIDED BY CHANGE IN TIME, \( \Delta T \), FROM P TO R. CALCULATE
55 THIS FROM THE GRAPH...
56
57 INCORRECT. YOU'VE CALCULATED THE CHANGE ON ONLY ONE AXIS OF THE GRAPH. THE SLOPE
58 OF THE LINE JOINING P AND R IS GIVEN BY CHANGE IN DISTANCE, \( \Delta S \),
59 DIVIDED BY CHANGE IN TIME, \( \Delta T \), FROM P TO R. CALCULATE THIS FROM
60 THE GRAPH...
WHAT HAPPENS TO THE SPEED AS WE MAKE THE TIME INTERVAL SMALLER AND SMALLER? LET'S CONTINUE WHAT WE DID WITH SHEET 3 BY CONSTRUCTING A TABLE.

<table>
<thead>
<tr>
<th>LENGTH OF INTERVAL (HRS)</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>.5</th>
<th>.25</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE OF LINE (MILES/HRS)</td>
<td>2</td>
<td>1.5</td>
<td>1.25</td>
<td>1.12</td>
<td>1.06</td>
<td>?</td>
</tr>
<tr>
<td>AVERAGE SPEED (MILES/HRS)</td>
<td>1.5</td>
<td>1.06</td>
<td>1.04</td>
<td>1.02</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>AVERAGE SPEED (MILES/HRS)</td>
<td>1.5</td>
<td>1.06</td>
<td>1.04</td>
<td>1.02</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0? SEND

STUDY THE TABLE CAREFULLY AND NOTE WHAT HAPPENS TO SLOPE AND AVERAGE SPEED AS THE LENGTH OF THE TIME INTERVAL SHRINKS FROM DEL(T)=4 DOWN TO 0. SEND

IS 1.006 IRIS?

THE LIMIT OF AVERAGE SPEED AS THE INTERVAL APPROACHES ZERO IS 1 M/H.

WE SEE THAT AS THE INTERVAL KEEPS GETTING SMALLER, IT SHRINKS TO A POINT AT T=2, AS SHOWN ON SHEET 3. THE SPEED AT T=2 IS JUST THE SLOPE OF THE LINE L WHICH TOUCHES THE CURVE AT ONLY ONE POINT P. THIS LINE IS CALLED THE TANGENT TO THE CURVE AT POINT P. SEND

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL APPROACHES ZERO?

AVERAGE SPEED (MILES/HRS) | 1.12| 1.06| 1.04| 1.02| 1.01| 1.008 |
|---------------------------|----|-----|-----|-----|-----|-------|

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0? SEND

0 IS 0 OR ZEROS

NO, THIS IS THE VALUE OF AVERAGE SPEED FROM T=2 TO T=6.

SPEED AS THE LENGTH OF THE INTERVAL TENDS TO 0 BUT AVERAGE SPEED DOES NOT.

LENGTH (HRS) | .5 | .25 | .15 | .10 | 0 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE (MILES/HRS)</td>
<td>1.12</td>
<td>1.06</td>
<td>1.04</td>
<td>1.02</td>
<td>1.01</td>
</tr>
<tr>
<td>AVERAGE SPEED (MILES/HRS)</td>
<td>1.12</td>
<td>1.06</td>
<td>1.04</td>
<td>1.02</td>
<td>1.01</td>
</tr>
</tbody>
</table>

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0? SEND

IS 1.016 ZEROS?

AVERAGE SPEED (MILES/HRS) | 1.12| 1.06| 1.04| 1.02| 1.01| 1.008 |
|---------------------------|----|-----|-----|-----|-----|-------|

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0? SEND

IS 1.006 ZEROS?

WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME T=2 HOURS?

SPEED AS THE TIME INTERVAL AROUND T=2 SHRINKS TO ZERO THE SHORTER THE TIME INTERVAL USED, THE CLOSER THE AVERAGE SPEED IS TO THE ACTUAL SPEED AT THAT INSTANT. THE ACTUAL SPEED AT THAT INSTANT IS JUST THE SLOPE OF THE TANGENT TO THE CURVE. SEND

LENGTH (HRS) | .5 | .25 | .15 | .10 | 0 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE (MILES/HRS)</td>
<td>1.12</td>
<td>1.06</td>
<td>1.04</td>
<td>1.02</td>
<td>1.01</td>
</tr>
<tr>
<td>AVERAGE SPEED (MILES/HRS)</td>
<td>1.12</td>
<td>1.06</td>
<td>1.04</td>
<td>1.02</td>
<td>1.01</td>
</tr>
</tbody>
</table>

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0? SEND

IS 1.016 ZEROS?

1.016 IS THE VALUE OF AVERAGE SPEED WHEN THE TIME INTERVAL HAS SHRUNK TO ZERO. LOOK AT THE TABLE AND TRY AGAIN...

TIME INTERVAL HAS SHRUNK TO ZERO. LOOK AT THE TABLE AND TRY AGAIN...

1.006 IS NOT EQUAL TO 0.

THE INSTANTANEOUS SPEED IS DEFINED AS THE VALUE OF AVERAGE SPEED WHEN THE TIME INTERVAL HAS SHRUNK TO ZERO. LOOK AT THE TABLE AND TRY AGAIN...

1.006 IS NOT EQUAL TO 0.

THE INSTANTANEOUS SPEED IS DEFINED AS THE VALUE OF AVERAGE SPEED WHEN THE TIME INTERVAL HAS SHRUNK TO ZERO. LOOK AT THE TABLE AND TRY AGAIN...

1.006 IS NOT EQUAL TO 0.

1.006 IS NOT EQUAL TO 0.

THE INSTANTANEOUS SPEED IS DEFINED AS THE VALUE OF AVERAGE SPEED WHEN THE TIME INTERVAL HAS SHRUNK TO ZERO. LOOK AT THE TABLE AND TRY AGAIN...

LOOK AT SHEET 4 WHICH IS THE GRAPH OF THE MOTION OF A FEATHER DROPPED.

LOOK AT SHEET 4 WHICH IS THE GRAPH OF THE MOTION OF A FEATHER DROPPED.

LOOK AT SHEET 4 WHICH IS THE GRAPH OF THE MOTION OF A FEATHER DROPPED.
1. From a tower, $s$ represents the distance of the feather from the ground.

2. What is the speed of the feather at $t=2$ sec?

3. Remember the relationship between speed and slope and then find the instantaneous speed at $t=2$ sec from the graph.

4. $s=8$ - FOURS - FOURS - MRS

5. The actual speed at $t=2$ sec is $-4$ feet/sec. This is the slope of the line which touches the curve at only one point $P$, the slope is negative since the distance $s$ is getting smaller as the time $t$ increases.

6. This means that $\Delta s(0)$ will be negative.

7. You're almost right. The change in distance $\Delta s(s)$ is given by:

8. As time gets bigger, $\Delta s(s)$ will be negative. Try again.

9. NO. The slope of the line which touches the curve at point $P$ represents the instantaneous speed of the feather at $t=2$.

1. Think about it and try again or please type review if you type. We will repeat the last section again from Sheet 2.

2. This actual speed is called the instantaneous speed of the feather.

3. The instantaneous speed is the slope of the straight line which touches the curve in Sheet 4 at the point $P$. This line is called the tangent to the curve at point $P$.

4. Less. Can I bits little specs thinks guess?

5. The instantaneous speed is written as $v=\lim (\Delta s/\Delta t)=$ as $\Delta t$ approaches 0. This is abbreviated by writing $v=ds/dt=\lim (\Delta s/\Delta t)$ as $\Delta t$ tends to 0.

6. The distance $s$ is easily obtained from the equation of motion.

7. Use the equation of motion $s=3t^2$ to evaluate $s$ at the point $t=1$...

8. We are simply calculating the distance at one point.

9. $s=3t^2$ $s=3^1*2$ $s=3*2=6$

10. Please type review. We will repeat the last section again from Sheet 2.

11. We're almost right. The change in distance $\Delta s(s)$ is given by:

12. As time gets bigger, $\Delta s(s)$ will be negative. Try again.

13. NO. The slope of the line which touches the curve at point $P$ represents the instantaneous speed of the feather at $t=2$.

14. Think about it and try again or please type review if you type. We will repeat the last section again from Sheet 2.

15. The slope of a line touching the curve of $s$ vs. $t$ at only one point.
THE LENGTH OF THE TIME INTERVAL INDICATED ON THE GRAPH IS $\Delta(t)$.

1. WHICH OF THE FOLLOWING REPRESENTS THE DISTANCE AT THE END OF THE
TIME INTERVAL, THAT IS, AT TIME $T=1+\Delta(t)$? PLEASE ANSWER A, B, C, D, OR E.

   A. $3(\Delta(t))^2$  
   B. $3(1+\Delta(t))^2$  
   C. $3(1+\Delta(t))$  
   D. $3t^2$  
   E. NONE OF THE ABOVE

USE THE EQUATION OF MOTION.

THE TIME AT THE END OF THE TIME INTERVAL IS $T=1+\Delta(t)$. THEN THE
DISTANCE AT THIS VALUE OF TIME IS GIVEN BY $S=3t^2+3(1+\Delta(t))^2$.

WHICH IS ALSO EQUAL TO $3(1+\Delta(t))^2$.

TRY AGAIN.

WRONG. THIS IS THE DISTANCE FROM THE ORIGIN AT A POINT IN TIME $T=\Delta(t)$.

IT IS NOT THE DISTANCE AT THE END OF THE INTERVAL WHICH STARTS AT $T=1$.

TRY AGAIN.

WS. THE DISTANCE IS GIVEN BY $S=3t^2$. YOU HAVE CHOSEN THE DISTANCE AT
THE END OF THE INTERVAL FOR AN EQUATION OF MOTION $S=3t^2+3(1+\Delta(t))$.

TRY AGAIN.

DO. ES.

WRONG. THE DISTANCE IS GIVEN BY $S=3t^2$ AND THE TIME AT THE END OF THE
TIME INTERVAL IS $T=1+\Delta(t)$.

TRY AGAIN.

WE WOULD LIKE TO FIND THE AVERAGE SPEED IN THIS TIME INTERVAL FROM $T=1$
TO $T=1+\Delta(t)$. THE CHANGE IN DISTANCE, $\Delta(s)$, IS GIVEN BY

$[\text{DISTANCE AT END OF INTERVAL}]-[\text{DISTANCE AT START OF INTERVAL}].$

THEN $\Delta(s) = (3+6t^2+3\Delta(t))^2-3$.

WHAT IS THE SIMPLIFIED FORM

OF $\Delta(s)/\Delta(t)$?

DO SOME ALGEBRA TO SIMPLIFY THIS EXPRESSION.

$6+3\Delta(t) 6+3\Delta(t) 6+3\Delta(t) 6+3\Delta(t) 3(2+\Delta(t)+3\Delta(t)+6\Delta(t)+3\Delta(t))$

$=8\Delta(s)/\Delta(t)=8\Delta(t)+3\Delta(t)+6\Delta(t))$

IN BOTH NUMERATOR AND DENOMINATOR. THIS IS THE AVERAGE SPEED
IN THE INTERVAL.

$\Delta(t)$

$\Delta(t)$

NOT QUITE. SIMPLIFY THE NUMERATOR AND THEN CANCEL $\Delta(t)$ FROM BOTH
NUMERATOR AND DENOMINATOR. GO AHEAD...

$3+6\Delta(t) 3+6\Delta(t) 3+6\Delta(t) 3+6\Delta(t) 3+6\Delta(t)$

NO. THE "$3" IN THE FIRST PART OF THE NUMERATOR CANCELS WITH THE "$3"
IN THE SECOND PART OF THE DENOMINATOR. THEN YOU CAN CANCEL $\Delta(t)$ FROM
NUMERATOR AND DENOMINATOR. TRY AGAIN...

$3+6\Delta(t) 3+6\Delta(t) 3+6\Delta(t)$

YOU SLIPPED UP WHEN YOU EXPANDED $3(1+\Delta(t))^2$. THE NUMERATOR
SHOULD BE $3(1+\Delta(t))^2+2$. THE LIMIT

$\Delta(t)$

$\Delta(t)$

RECALLING THAT INSTANTANEOUS SPEED IS THE LIMIT OF AVERAGE SPEED AS THE
TIME INTERVAL SHINKS TO ZERO, THAT IS, AS $\Delta(t)$ APPROACHES ZERO.

WHAT IS THE INSTANTANEOUS SPEED AT TIME $T=1$ SEC.?...

FIND THE LIMIT OF $\Delta(s)/\Delta(t)$ AS $\Delta(t)$ APPROACHES 0.

$S=6\Delta(s)$

$\Delta(t)$

FIND $\lim_{\Delta(t)\to 0} \Delta(s)/\Delta(t) = 15$.

$\Delta(s)$

$\Delta(t)$

THE LIMIT AS $\Delta(t)$ TENDS TO 0 IS THE VALUE OF $6\Delta(t)$ WHEN $\Delta(t)=0$.

YOU SEE TO BE UNCLEAR ABOUT WORKING OUT LIMITS. YOU SHOULD DO SOME WORK ON
LIMITS FOR A FEW MINUTES BEFORE GOING ON WITH THE MAIN LESSON.

PLEASE ENTER THE WORD... LIMIT, OR TRY AGAIN IF YOU WISH.

LIMTS

LIMTS
LET S = 3T + 7. When T = 2, it is easy to see that S = 13. But how does S behave when T is close to 2? Examine the table given below.

<table>
<thead>
<tr>
<th>T</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>2.1</td>
<td>12.9</td>
</tr>
<tr>
<td>2.01</td>
<td>12.999</td>
</tr>
<tr>
<td>2.001</td>
<td>12.99999</td>
</tr>
</tbody>
</table>

Does S seem to be getting closer to 13 as T gets closer to 2? Yes or not?

Yes. OK, thinks sure.

We say that if S = 3T + 7, then S approaches 13 as T approaches 2 and write the limit (3T + 7) as T approaches 2 is equal to 13.

No. Does S seem to be getting closer to 13 as T gets closer to 2? Yes or not?

No. Think about it. If S = 3T + 7, then S approaches 13 as T approaches 2.

The limit (3T + 7) as T approaches 2 is equal to 13.

Look at the table closely and answer again or ask for help.

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201

GOTO 16
AS  BS  CS  DS  NOTS  SOMES  RODERS  VERTS

GOTO 19
19  19
2  2  8

WHICH CATEGORY BELOW A, B, C, OR D BEST DESCRIBES YOUR REACTION TO THE STATEMENT.

1. I FEEL AT EASE.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

2. I AM RELAXED.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

3. I FEEL CALM.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

4. I AM JITTERY.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

5. I FEEL EXITED.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

6. I FEEL ANGRY.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

7. I FEEL SHOCKED.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

8. I FEEL SHY.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

9. I FEEL SAD.
   A NOT AT ALL C MODERATELY SO
   B SOMEWHAT D VERY MUCH SO
   PLEASE A, B, C, OR D.
   SEND

10. I FEEL TENSE.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

11. I FEEL ANNOYED.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

12. I FEEL NERVOUS.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

13. I FEEL STRESSED.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

14. I FEEL CONFUSED.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

15. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

16. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

17. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

18. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

19. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

20. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

21. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

22. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

23. I FEEL UNCERTAIN.
    A NOT AT ALL C MODERATELY SO
    B SOMEWHAT D VERY MUCH SO
    PLEASE A, B, C, OR D.
    SEND

LETS.TH ONCE MORE TO FIND THE INSTANTANEOUS SPEED USING THE EQUATION
OF MOTION, S=T*2. FIRST, WHICH OF THE FOLLOWING IS THE AVERAGE SPEED BETWEEN
T=2 AND T=2+DEL(T) ?

A. (2+DEL(T))*2-2*2
B. (2+DEL(T))*2-2*2
C. (2+DEL(T))*2-2*2 / (2+DEL(T))*2-2*2
D. (2+DEL(T))*2-2*2 / (2+DEL(T))*2-2*2

DO SOME ALGEBRA TO GET DEL(S) AND DEL(T) BEFORE FINDING AVERAGE SPEED IN
THIS INTERVAL.
202

AS BS
NO. THIS REPRESENTS DISTANCE. THE DISTANCE AT T=2 IS S=T+2=2+2=4 AND
THE DISTANCE AT T=2+DEL(T) IS S=(2+DEL(T)+2). YOU MUST DIVIDE DEL(S)
BY DEL(T). YOU SHOULD REPEAT THE MATERIAL DEALING WITH SHEET 5 TO BECOME
CLEAR ABOUT THIS.

EITHER TYPE „REVIEW” OR ANSWER AGAIN.

BS
NO. THE AVERAGE SPEED IS DEL(S)/DEL(T) IN THE INTERVAL.
DEL(S)=FINAL DISTANCE-INITIAL DISTANCE=2+DEL(T)+2-2-2 AND
DEL(T)=FINAL TIME-INITIAL TIME=(2+DEL(T)-2).

SIMPLIFY DEL(S) AND DEL(T) AND DIVIDE THEM. YOU SHOULD REPEAT THE MATERIAL
DEALING WITH SHEET 5 TO BE CLEAR ABOUT THIS. TYPE „REVIEW” OR TRY AGAIN.

REVS NS DS OKS
GOT IT

4 3 5 3 2
WHAT IS THE INSTANTANEOUS SPEED AT T=2?
REMEMBER THE RELATIONSHIP BETWEEN AVERAGE SPEED AND INSTANTANEOUS SPEED
AND THEN GO AHEAD...

4 S
4.5 FOURS
THE AVERAGE SPEED IS DEL(S)/DEL(T)=(2+DEL(T)+2-2-2)/2+DEL(T)-2

SIMPLIFY THE NOUNERATOR AND DENOMINATOR GIVES
DEL(S)/DEL(T)=(2+DEL(T)+DEL(T)+2)/DEL(T) NEW CANCEL DEL(T)
FROM NUMERATOR AND DENOMINATOR AND WE END UP WITH 4+DEL(T).

THE LIMIT OF 4+DEL(T) AS DEL(T) TENDS TO ZERO IS 4, WHICH IS THE INST. SPEED SEND
0/0
0/0 ZEROS OS 0/0

YOU DIDN'T SIMPLIFY THE NUMERATOR AND DENOMINATOR FIRST IN DEL(S)/DEL(T)
BEFORE FINDING THE LIMIT. DO THIS AND THEN CANCEL DEL(T) FROM BOTH
NUMERATOR AND DENOMINATOR BEFORE FINDING THE LIMIT OF DEL(S)/DEL(T).

GO AHEAD AND TRY AGAIN...

2 S
1 5 DEL
YOU SEEM TO HAVE SLIPPED UP IN YOUR CALCULATIONS. SIMPLIFYING THE
NUMERATOR OF DEL(S)/DEL(T) GIVES (4+DEL(T)+DEL(T)+2)-4=DEL(T)+DEL(T)+2

SIMPLIFY THE DENOMINATOR GIVES DEL(T), CANCEL DEL(T) FROM NUMERATOR
AND DENOMINATOR. THEN FIND THE LIMIT OF THE REMAINING EXPRESSION.

$/\$ +$

NOT QUITE. YOU HAVEN'T REDUCED THE EXPRESSION TO SIMPLEST FORM.
YOU SHOULD SIMPLIFY THE NUMERATOR AND DENOMINATOR AND CANCEL
DEL(T) FROM BOTH OF THESE. THEN FIND THE LIMIT OF THE REMAINING EXPRESSION.

SEND 25
2 2 2
CONGRATULATIONS! YOU HAVE COMPLETED A CAL LESSON. I HOPE THAT YOU
ENJOYED OUR CONVERSATION AS MUCH AS I DID AND THAT YOU LEARNED SOMETHING
TOO. DID YOU ENJOY THIS METHOD OF LEARNING?

ANSWER YES OR NO.

YES NS
IF YOU WISH TO MAKE ANY COMMENTS ABOUT THE LESSON, ASK THE INSTRUCTOR TO
PROVIDE YOU WITH A CORRECT SHEET.

FILE

PLEASE ANSWER YES OR NO.

FILE

T2 1

4 8 2 2 3
LET'S STUD: THE MOTION OF A BOAT AS IT LEAVES A DOCK.
SUPPOSE THAT IT'S MOVING AT A CONSTANT SPEED OF 10 MILES/HOUR.
WHAT IS THE DISTANCE S OF THE BOAT FROM THE DOCK AT ANY TIME T?

REMEMBER THAT DISTANCE = (SPEED) (TIME). WRITE AN EQUATION FOR S IN TERMS OF T. THIS IS SIMPLY THE FAMILIAR DISTANCE = (SPEED) (TIME) EQUATION, WITH SPEED V BEING CONSTANT AT 10 MILES/HOUR.

10S/T $ T=10S$ NO. DISTANCE = (SPEED) (TIME). THE SPEED IS 10 MILES PER HOUR AND THE TIME IS T. WRITE AN EQUATION FOR S IN TERMS OF T. GO AHEAD......

10 $ T. 5$ NO. DISTANCE = (SPEED) (TIME). THE SPEED IS 10 MILES PER HOUR AND THE TIME IS T. WRITE AN EQUATION FOR S IN TERMS OF T. GO AHEAD......

10S $ T. 10S$ NO. DISTANCE = (SPEED) (TIME). THE SPEED IS 10 MILES PER HOUR AND THE TIME IS T. WRITE AN EQUATION FOR S IN TERMS OF T. GO AHEAD......

T 2 4 8 2

LOOK AT SHEET 1 THAT WAS GIVEN TO YOU. THE GRAPH INDICATES HOW FAR THIS BOAT IS FROM THE DOCK AT ANY TIME. THE MOTION IN A TIME INTERVAL T=2 TO T=6 HOURS?

YOU NEED TO OBTAIN THE CHANGE IN DISTANCE AND THE CHANGE IN TIME BETWEEN THESE TWO POINTS IN ORDER TO CALCULATE THE SLOPE. GO AHEAD......

THE SLOPE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME. WE WRITE THIS AS SLOPE = DEL(S)/DEL(T) WHICH IS EQUAL TO (60-20)/(6-2)=10 MILES/HOUR.

WRONG. THE SLOPE OF THE STRAIGHT LINE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME BETWEEN THESE TWO POINTS. NOW, GO AHEAD AND WORK OUT THE SLOPE...

60/20 20/20

WRONG. THE SLOPE OF THE STRAIGHT LINE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME BETWEEN THESE TWO POINTS. NOW, GO AHEAD AND WORK OUT THE SLOPE...

80/20 5/2

WRONG. THE SLOPE OF THE STRAIGHT LINE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME BETWEEN THESE TWO POINTS. NOW, GO AHEAD AND WORK OUT THE SLOPE...

3 4 8 2

WHAT IS THE SLOPE OF THE LINE IN THE TIME INTERVAL T=4 TO T=8 HOURS?

YOU NEED TO OBTAIN THE CHANGE IN DISTANCE AND THE CHANGE IN TIME BETWEEN THESE TWO POINTS IN ORDER TO CALCULATE THE SLOPE. GO AHEAD......


1/10S $ 1/10S=0.1$ 4/40S 2/20S 6/60S 8/80S 8-6-40S=4/80-S THAT IS INCORRECT. SLOPE IS CHANGE IN DISTANCE DIVIDED BY CHANGE IN TIME BETWEEN THESE TWO POINTS. NOW, GO AHEAD AND CALCULATE THIS SLOPE...

10S 80/60 4/40S 4/40S THAT IS INCORRECT. SLOPE IS CHANGE IN DISTANCE DIVIDED BY CHANGE IN TIME BETWEEN THESE TWO POINTS. NOW, GO AHEAD AND CALCULATE THIS SLOPE...
SHEET 2 ILLUSTRATES THE MOTION OF A SECOND BOAT

COMPUTE THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL FROM T=2 TO T=6 HRS.

THE AVERAGE SPEED IS SIMPLY THE CHANGE IN DISTANCE DIVIDED BY THE
CHANGE IN TIME. THIS IS GIVEN BY

\[ \text{Average Speed} = \frac{\text{Change in Distance}}{\text{Change in Time}} \]

\[ \text{Average Speed} = \frac{(9-1)/(6-2)}{6-2} = 2 \text{ MILES/HOUR} \]

PROCEED EXACTLY AS BEFORE.

\[ \text{Average Speed} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

LOOK AT SHEET 3, WHICH IS JUST THE GRAPH IN SHEET 2 WITH THREE POINTS
P, Q, AND R INDICATED ON IT.

WHAT IS THE SLOPE OF THE LINE SEGMENT JOINING THE POINTS P AND Q?

YOU NEED TO KNOW THE CHANGE IN DISTANCE AND THE CHANGE IN TIME BETWEEN
P AND Q IN ORDER TO CALCULATE THE SLOPE OF THE LINE SEGMENT. GO AHEAD...

\[ \text{Slope} = \frac{\text{Change in Distance}}{\text{Change in Time}} \]

\[ \text{Slope} = \frac{(9-1)/(6-2)}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

THE AVERAGE SPEED IS THE SAME AS THE AVERAGE SPEED OF THE BOAT BETWEEN P AND Q.

CALCULATE THIS FROM THE GRAPHS...

\[ \text{Slope} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

WHEN THE AVERAGE SPEED IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME.

\[ \text{Average Speed} = \frac{\text{Distance}}{\text{Time}} \]

\[ \text{Average Speed} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

Lett's take a smaller size interval than before on the graph in Sheet 3.

WHAT IS THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL T=2 TO T=4 HOURS?

\[ \text{Average Speed} = \frac{\text{Change in Distance}}{\text{Change in Time}} \]

\[ \text{Average Speed} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

THE AVERAGE SPEED OVER THIS INTERVAL.

NOTICE THAT THE AVERAGE SPEED IS NO LONGER CONSTANT!!

IF THE GRAPH IS NOT A STRAIGHT LINE, THE SLOPE IS NO LONGER CONSTANT.

NO. THE AVERAGE SPEED IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME FROM T=2 TO T=4. CALCULATE THIS FROM THE GRAPHS...

\[ \text{Average Speed} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

NO. THE AVERAGE SPEED IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME FROM T=2 TO T=4. CALCULATE THIS FROM THE GRAPHS...

\[ \text{Average Speed} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]

NO. THE AVERAGE SPEED IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME FROM T=2 TO T=4. CALCULATE THIS FROM THE GRAPHS...

\[ \text{Average Speed} = \frac{9-1}{6-2} = \frac{8}{4} = 2 \text{ MILES/HOUR} \]
<table>
<thead>
<tr>
<th>LENGTH OF INTERVAL (HRS)</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>0.5</th>
<th>0.25</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE OF LINE (MILES/HR)</td>
<td>2</td>
<td>1.5</td>
<td>1.25</td>
<td>1.12</td>
<td>1.06</td>
<td>1</td>
</tr>
<tr>
<td>AVERAGE SPEED (MILES/HR)</td>
<td>2</td>
<td>1.5</td>
<td>1.25</td>
<td>1.12</td>
<td>1.06</td>
<td>1</td>
</tr>
</tbody>
</table>

**What is the limit of average speed as the interval shrinks to size 0?**

To study the table carefully and note what happens to slope and average speed as the length of the time interval shrinks from \( \Delta t = 4 \) down to 0.

- **Length:** 1.006 (1 M/HR)
- **Slope:** 1.006
- **Average speed:** 1.006

**What is the limit of average speed as the interval approaches zero?**

The limit of average speed as the interval approaches zero is 1 M/HR.

Be sure that as the interval keeps getting smaller, it shrinks to a point at \( t = 2 \), as shown on Sheet 3. The speed at \( t = 2 \) is just the slope of the line which touches the curve at only one point \( P \). This line is called the tangent to the curve at point \( P \).

**What is the limit of average speed as the interval shrinks to size 0?**

This is the speed at the instant of time \( t = 2 \) hours.

As well as Sheet 3, then try to answer...

- **Length:** 1.006 (1 M/HR)
- **Slope:** 1.006
- **Average speed:** 1.006

**What is the value of speed?**

The speed at \( t = 2 \) is the limit of the average speed that we obtained as we shrank the interval starting at \( t = 2 \) down to size zero.

- **Length:** 1.006
- **Slope:** 1.006
- **Average speed:** 1.006

**What is this value of speed?**

This value of speed is undefined.
WHAT IS THE SPEED OF THE FEATHER AT T=2 SEC?
SEND
REMEMBER THE RELATIONSHIP BETWEEN SPEED AND SLOPE AND THEN FIND THE
INSTANTANEOUS SPEED AT T=2 SEC. FROM THE GRAPHS:
SEND
-4 $ FOURS - FOURS -4 $ IS-4 $ =-8 $
THE ACTUAL SPEED AT T=2 SEC. IS -4 FEET/SEC. THIS IS THE SLOPE OF
THE LINE WHICH TOUCHES THE CURVE AT ONLY ONE POINT P. THE SLOPE IS
NEGATIVE SINCE THE DISTANCE S IS GETTING SMALLER AS THE TIME T INCREASES.
THIS MEANS THAT DEL(S) WILL BE NEGATIVE.
SEND
NO. FIND THE INSTANTANEOUS SPEED OF THE FEATHER AT T=2 SEC. BY FINDING THE
SLOPE OF THE LINE WHICH TOUCHES THE CURVE AT THE POINT P. GO AHEAD...
SEND
-1. SENS
6$ 25 35 15 -3$ -15
NO. FIND THE INSTANTANEOUS SPEED OF THE FEATHER AT T=2 SEC. BY FINDING THE
SLOPE OF THE LINE WHICH TOUCHES THE CURVE AT THE POINT P. GO AHEAD...
SEND
GOTO 4

1 1 3

THIS ACTUAL SPEED IS CALLED THE INSTANTANEOUS SPEED OF THE FEATHER
AT T=2 SEC. THE INSTANTANEOUS SPEED IS THE SLOPE OF THE STRAIGHT LINE
WHICH TOUCHES THE CURVE IN SHEET 4 AT THE POINT P. THIS LINE IS CALLED
THE TANGENT TO THE CURVE AT POINT P. DO YOU UNDERSTAND?
SEND
IF WE'VE DEVELOPED THE IDEA OF SLOPE REPRESENTING SPEED, THEN SLOPE OF A
LINE JOINING TWO POINTS ON THE CURVE IS AVERAGE SPEED. THE SLOPE OF A
LINE TOUCHING THE CURVE AT ONE POINT IS INSTANTANEOUS SPEED. IS IT CLEAR?
SEND
YES OKS LITTLE SURE THINKS GUESS
THE INSTANTANEOUS SPEED IS WRITTEN AS V-LIMIT(D(S)/DEL (T )) AS
DEL(T ) APPROACHES 0. THIS IS ABBREVIATED BY WRITING
V=DS/DT=LIMIT((DEL (S))/DEL (T )) AS DEL (T ) TENDS TO 0.
DS/DT IS CALLED THE DERIVATIVE OF S WITH RESPECT TO T AND REPRESENTS
THE SLOPE OF A LINE TOUCHING THE CURVE OF S VS. T AT ONLY ONE POINT.
SEND
NO. USE THE EQUATION OF MOTION, S=3T*2 TO OBTAIN THE DISTANCE S AT T=1.
GO AHEAD...
SEND
THE LENGTH OF THE TIME INTERVAL INDICATED ON THE GRAPH IS DEL (T).
WHICH OF THE FOLLOWING REPRESENTS THE DISTANCE AT THE END OF THE
TIME INTERVAL, THAT IS, AT TIME T=1+DEL(T)? PLEASE ANSWER A, B, C, D, OR E.
SEND
A 3(1+DEL(T))$ 2
B 3(1+DEL(T))$2
C 3(1+DEL(T))$ 2
D 3T$2
E 3T$2
THE TIME AT THE END OF THE TIME INTERVAL IS T = 1 + DEL(T). THEN THE
DISTANCE AT THIS VALUE OF T IS GIVEN BY S = 3T^2 = 3(1 + DEL(T))^2
WHICH IS ALSO EQUAL TO 3 + 6DEL(T) + 3DEL(T)^2

AS

THE EQUATION OF MOTION IS S = 3T^2. THE TIME INTERVAL OF LENGTH DEL(T)
BEGIN AT T = 1. FIND THE VALUE OF T AT THE END OF THE INTERVAL AND
SUBSTITUTE THIS VALUE INTO THE EQUATION OF MOTION TO GET S...

CS

THE EQUATION OF MOTION IS S = 3T^2. THE TIME INTERVAL OF LENGTH DEL(T)
BEGIN AT T = 1. FIND THE VALUE OF T AT THE END OF THE INTERVAL AND
SUBSTITUTE THIS VALUE INTO THE EQUATION OF MOTION TO GET S...

DEL / 2

THE EQUATION OF MOTION IS S = 3T^2. THE TIME INTERVAL OF LENGTH DEL(T)
BEGIN AT T = 1. FIND THE VALUE OF T AT THE END OF THE INTERVAL AND
SUBSTITUTE THIS VALUE INTO THE EQUATION OF MOTION TO GET S...

13

WE WOULD LIKE TO FIND THE AVERAGE SPEED IN THIS TIME INTERVAL FROM T = 1
TO T = 1 + DEL(T). THE CHANGE IN DISTANCE, DEL(S), IS GIVEN BY
(DISTANCE AT END OF INTERVAL) - (DISTANCE AT START OF INTERVAL).

THEN DEL(S) = (3 + 6DEL(T) + 3DEL(T)^2) - 3

WHAT IS THE SIMPLIFIED FORM
OF DEL(S)/DEL(T) ?

DO SOME ALGEBRA TO SIMPLIFY THIS EXPRESSION.

DEL(S)/DEL(T) = (3 + 6DEL(T) + 3DEL(T)^2)/DEL(T) = 6 + 6DEL(T)
SINCE DEL(T) CANCELS
IN BOTH NUMERATOR AND DENOMINATOR. THIS IS THE AVERAGE SPEED
IN THE INTERVAL.

WRONG. SIMPLIFY THE NUMERATOR BY REMOVING THE BRACKETS AND COLLECTING
LIKE TERMS. THEN CANCEL DEL(T) FROM BOTH NUMERATOR AND DENOMINATOR.
CHECK YOUR ALGEBRA AND TRY AGAIN...

WRONG. SIMPLIFY THE NUMERATOR BY REMOVING THE BRACKETS AND COLLECTING
LIKE TERMS. THEN CANCEL DEL(T) FROM BOTH NUMERATOR AND DENOMINATOR.
CHECK YOUR ALGEBRA AND TRY AGAIN...

WRONG. SIMPLIFY THE NUMERATOR BY REMOVING THE BRACKETS AND COLLECTING
LIKE TERMS. THEN CANCEL DEL(T) FROM BOTH NUMERATOR AND DENOMINATOR.
CHECK YOUR ALGEBRA AND TRY AGAIN...

RECALLING THAT INSTANTANEOUS SPEED IS THE LIMIT OF AVERAGE SPEED AS THE
TIME INTERVAL SHRINKS TO ZERO, THAT IS, AS DEL(T) APPROACHES 0.

WHAT IS THE INSTANTANEOUS SPEED AT TIME T = 1?

FIND THE LIMIT OF DEL(S)/DEL(T) AS DEL(T) APPROACHES 0.
6S

GOTO 15

3 T 2 7 3

GOTO 15
Let's examine the behavior of the function $S = 3T + 7$ when $T$ is close to 2. To do this, we can evaluate $S$ for values of $T$ close to 2 and observe the trend.

<table>
<thead>
<tr>
<th>$T$</th>
<th>2.001</th>
<th>2.0001</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S$</td>
<td>13.003</td>
<td>13.00003</td>
</tr>
</tbody>
</table>

We can see that as $T$ gets closer to 2, $S$ gets closer to 13. This suggests that the limit of $S$ as $T$ approaches 2 is 13.

We can also examine the table given below to further confirm this.

<table>
<thead>
<tr>
<th>$T$ (close to 2)</th>
<th>$S = 3T + 7$ (close to 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0001</td>
<td>13.00003</td>
</tr>
</tbody>
</table>

Now, let's calculate the limit of $S = 3T + 7$ as $T$ approaches 2.

The limit of $S = 3T + 7$ as $T$ approaches 2 is equal to 13.

Let's look at the table closely and answer again or ask for help.

The limit of $S$ as $T$ tends to a particular value seems to be simply the value of $S$ at that value of $T$. This is generally true except only under certain conditions, which you will learn about later in your Calculus course.

Find the limit of $S = 20 - 6T$ as $T$ approaches 3.

The value of $S$ at the point $T = 3$ is 2. As we take the value of $T$ closer and closer to 3, the value of $S$ gets closer and closer to 2.

Find the value of $S$ at the point $T = 3$...

1. **No. Find the value of $S$ at the point $T = 3$...**
2. **No. Find the value of $S$ at the point $T = 3$...**
3. **No. Find the value of $S$ at the point $T = 3$...**

We can see that as $T$ gets closer and closer to 3, the value of $S$ gets closer and closer to 2.

Find the limit of $S = 3T + 7$ as $T$ approaches 2. Does $S$ seem to be getting closer to 13 as $T$ gets closer to 2? Yes or not? Yes.

Let's take a short break from the lesson. I'd like to know how you feel...

- Right now, which of the categories below describe best your reaction...now...
  1. Not at all
  2. Moderately so
  3. Somewhat
  4. Very much so

Please answer A, B, C, or D.

Answer: A, B, C, or D to describe your reaction right now to the statement...

I feel at ease...

Which category best describes your reaction to the statement...

- Not at all
- Moderately so
- Somewhat
- Very much so

Answer: A, B, C, or D.
PLEASE A,B,C,OR D.

BOS YES

GOTO19

AS BS CS DS NOTS SORES MODES VERTS

2 2 8

I AM RELAXED.

A NOT AT ALL C MODERATELY SO
B SOMEWHAT D VERY MUCH SO

PLEASE ANSWER A,B,C,OR D.

ANSWER A,B,C,OR D TO THE STATEMENT... I AM RELAXED.

BOS YES

GOTO20

AS BS CS DS NOTS SORES MODES VERTS

2 2 8

I FEEL CALM.

A NOT AT ALL C MODERATELY SO
B SOMEWHAT D VERY MUCH SO

PLEASE ANSWER A,B,C,OR D.

ANSWER A,B,C,OR D TO THE STATEMENT... I FEEL CALM.

BOS YES

GOTO21

AS BS CS DS NOTS SORES MODES VERTS

2 2 8

I AM JITTERY.

A NOT AT ALL C MODERATELY SO
B SOMEWHAT D VERY MUCH SO

PLEASE ANSWER A,B,C,OR D.

ANSWER A,B,C,OR D TO THE STATEMENT... I AM JITTERY.

BOS YES

GOTO22

AS BS CS DS NOTS SORES MODES VERTS

2 2 8

LET'S TRY ONCE MORE TO FIND THE INSTANTANEOUS SPEED USING THE EQUATION OF MOTION, S=1/2, FIRST, WHICH OF THE FOLLOWING IS THE AVERAGE SPEED BETWEEN T=2 AND T=2*DEL(T)?

A (2*DEL(T))^2 / 2  B (2*DEL(T))^2 / 2-2*2
C (2*DEL(T))^2 / 2-2*2 / (2*DEL(T))^2 / 2  D (2*DEL(T))^2 / 2-DEL(T)^2 / 2

DO SOME ALGEBRA TO GET DEL(S) AND DEL(T) BEFORE FINDING AVERAGE SPEED IN THIS INTERVAL.

The average speed is simply DEL(S)/DEL(T) IN THE INTERVAL, WHICH IS GIVEN BY (2*DEL(T))^2 / 2-2*2 / (2*DEL(T))^2 / 2.

AS BS

Wrong. Look at an interval starting at T=2 and ending at T=2*DEL(T).

The average speed is given by DEL(S)/DEL(T) IN THIS INTERVAL.

You should repeat the material dealing with sheet 5 to become CLEAR ABOUT THIS.

EITHER TYPE ... REVIEW OR ANSWER AGAIN.

AS BS

Wrong. Look at an interval starting at T=2 and ending at T=2*DEL(T).

The average speed is given by DEL(S)/DEL(T) IN THIS INTERVAL.
CONGRATULATIONS! YOU HAVE COMPLETED A CAI LESSON. I HOPE THAT YOU ENJOYED OUR CONVERSATION AS MUCH AS I DID AND THAT YOU LEARNED SOMETHING.

TOO, DID YOU ENJOY THIS METHOD OF LEARNING?

ANSWER YES OR NO.

YES $ NO $

IF YOU WISH TO MAKE ANY COMMENTS ABOUT THE LESSON, ASK THE INSTRUCTOR TO PROVIDE YOU WITH A COMMENT SHEET. GOOD-BYE FOR NOW...

FILE $
THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND

THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND

THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND

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THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND

THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND

THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND
THIS IS THE SAME AS THE AVERAGE SPEED OF THE BOAT BETWEEN P AND Q.  
9/6$ 1/2$ 1.5$ .5$  
THAT'S NOT THE ANSWER I'M LOOKING FOR.  THINK ABOUT IT AND TRY AGAIN...  
9$ 18$ 6$ NO. TRY AGAIN.....  
8$ 8$  
YOUR ANSWER IS INCORRECT. THINK ABOUT THE PROBLEM AND TRY AGAIN...  

4.5.2.1  
LET'S TAKE A SMALLER SIZE INTERVAL THAN BEFORE ON THE GRAPH IN SHEET 3.  
WHAT IS THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL T=2 TO T=4 HOURS?  
PROCEED EXACTLY AS BEFORE.  
1.5$ 3/2$ 1+1/2$ 11/2$ 1 1/2$ 4-1/4-2$ (5-1)/(4-SHALS  
THE AVERAGE SPEED IS V-DEL(S)/DEL(T) = (4-1)/(4-2)=1.5 M/HR.  
THE SLOPE OF THE LINE SEGMENT JOINING P AND R IS AGAIN THE SAME AS  
THE AVERAGE SPEED OVER THIS INTERVAL.  
NOTICE THAT THE AVERAGE SPEED IS NO LONGER CONSTANT!!  
IF THE GRAPH IS NOT A STRAIGHT LINE THE SLOPE IS NO LONGER CONSTANT.  
1 $ 1/2$ 1/2$ 1MIS  
WRONG. TRY AGAIN...  
3$ 2$  
THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD.  
4$ 3$ 2$ 3$ 5  
WHAT HAPPENS TO THE SPEED AS WE MAKE THE TIME INTERVAL SMALLER AND SMALLER? LET'S CONTINUE WHAT WE DID WITH SHEET 3 BY CONSTRUCTING A TABLE.  
LENGTH OF INTERVAL(HRS)** 4 2 1 .5 .25 0  
SLOPE OF LINE(MILES/HR)** 2 1.5 1.25 .9 .12 1.06 7  
AVERAGE SPEED(MILES/HR)** 2 1.5 1.25 .9 .12 1.06 7  
WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0?  
STUDY THE TABLE CAREFULLY AND NOTE WHAT HAPPENS TO SLOPE AND AVERAGE  
SPEED AS THE LENGTH OF THE TIME INTERVAL SHRINKS FROM DEL(T)=4 DOWN TO 0.  
1$ 1.00$ 1.15  
THE LIMIT OF AVERAGE SPEED AS THE INTERVAL APPROACHES ZERO IS 1 M/HR.  
WE SEE THAT AS THE INTERVAL BEGINS TO GET SMALLER, THE SLOPE OF THE LINE L WHICH TOUCHES THE CURVE AT ONLY ONE POINT P, THIS LINE IS  
CALLED THE TANGENT TO THE CURVE AT POINT P.  
2$ 2$  
YOUR ANSWER IS INCORRECT. THINK ABOUT THE PROBLEM AND TRY AGAIN...  
OF ZERO  
THAT'S NOT THE ANSWER I'M LOOKING FOR. THINK ABOUT IT AND TRY AGAIN...  
1$ 1.03$ 0.7  
DEFINING NO LIMITS NO LIMITS  
YOUR REPLY IS NOT CORRECT. RECONSIDER YOUR ANSWER AND TRY AGAIN...  
8$ 4$ 5$ 2$ 3$ 5  
WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME T=2 HOURS?  
THIS IS THE SPEED AT THE INSTANT OF TIME T=2 HRS. STUDY THE TABLE ABOVE  
AS WELL AS SHEET 3. THEN TRY TO ANSWER...  
1$ 1.00$ 1.15  
THE SPEED AT TIME T=2 HOURS IS DEFINED AS THE LIMIT OF THE AVERAGE  
SPEED AS THE TIME INTERVAL ABOUT T=2 SHRINKS TO ZERO. THE SHORTER THE  
TIME INTERVAL USED, THE CLOSER THE AVERAGE SPEED IS TO THE ACTUAL SPEED  
AT THAT INSTANT. THE ACTUAL SPEED AT THAT INSTANT IS JUST THE SLOPE  
OF THE TANGENT TO THE CURVE.  
2$ 2$  
NO. THINK ABOUT IT AND TRY AGAIN...  
0$ 0$ 0$ ZEROS
TOUB RESPONSE IS INCORRECT. TRY TO ANSWER AGAIN... SEND
1.03 1.01 NO LIMITS NOTLIMITS UNDEFINEDS SEND
WRONG. TRY AGAIN........ SEND

9 4 6 2 7 3
LOOK AT SHEET 4 WHICH IS THE GRAPH OF THE MOTION OF A FEATHER DROPPED
FROM A TOWER. S REPRESENTS THE DISTANCE OF THE FEATHER FROM THE GROUND.
WHAT IS THE SPEED OF THE FEATHER AT T=2 SEC.? SEND
REMEMBER THE RELATIONSHIP BETWEEN SPEED AND SLOPE AND THEN FIND THE
INSTANTANEOUS SPEED AT T=2 SEC. FROM THE GRAPH.
-4 $ -4 POURS - POURS -4 MIS 15-4 $ =-4 $ SEND
THE ACTUAL SPEED AT T=2 SEC. IS -4 FEET/SEC. THIS IS THE SLOPE OF
THE LINE WHICH TOUCHES THE CURVE AT ONLY ONE POINT P. THE SLOPE IS
NEGATIVE SINCE THE DISTANCE S IS GETTING SMALLER AS THE TIME T INCREASES.
THIS MEANS THAT DEL(S) WILL BE NEGATIVE. SEND
YOUR ANSWER IS INCORRECT. THINK ABOUT THE PROBLEM AND TRY AGAIN...
THINK ABOUT IT AND TRY AGAIN OR PLEASE TYPE REVIEW
IF YOU TYPE... REVIEW, WE WILL REPEAT THE LAST SECTION AGAIN FROM SHEET 2.
REYES NOT DOMS
GOTO 4 10 2 7 3
THIS ACTUAL SPEED IS CALLED THE INSTANTANEOUS SPEED OF THE FEATHER
AT T=2 SEC. THE INSTANTANEOUS SPEED IS THE SLOPE OF THE STRAIGHT LINE
WHICH TOUCHES THE CURVE IN SHEET 4 AT THE POINT P. THIS LINE IS CALLED
THE TANGENT TO THE CURVE AT POINT P. DO YOU UNDERSTAND?
WE'VE DEVELOPED THE IDEA OF SLOPE REPRESENTING SPEED. THE SLOPE IS
A LINE JOINING TWO POINTS ON THE CURVE IS AVERAGE SPEED. THE SLOPE OF A
LINE TOUCHING THE CURVE AT ONE POINT IS INSTANTANEOUS SPEED IS IT CLEAR?
YES OKS BITS LITTLES SURES THINKS GUESSES
THE INSTANTANEOUS SPEED IS WRITTEN AS V=LIMIT(DEL(S)/DEL(T)) AS
DEL(T) APPROACHES 0. THIS IS ABBREVIATED BY WRITING
V=DS/DT=LIMIT(DEL(S)/DEL(T)) AS DEL(T) TENDS TO 0.
DS/DT IS CALLED THE DERIVATIVE OF S WITH RESPECT TO T AND REPRESENTS
THE SLOPE OF A LINE TOUCHING THE CURVE OF S VS. T AT ONLY ONE POINT.
NO DOMS NOTS
THEN READ IT AGAIN AND ASK FOR HELP.
11 4 6 2 7 3
NOW LET'S FIND THE INSTANTANEOUS SPEED BY USING THE EQUATION OF MOTION.
SHEET 5 ILLUSTRATES THE GRAPH OF THE EQUATION OF MOTION, S=3T^2
WHICH LOOK AT THE TIME INTERVAL BEGINNING AT T=1.
WHAT IS THE DISTANCE S AT THE BEGINNING OF THIS TIME INTERVAL?
USE THE EQUATION OF MOTION.
S=3T^2 3 T HRES 3 (1) #25
THE DISTANCE S IS EASILY OBTAINED FROM THE EQUATION OF MOTION.
S=3T^2=3(1)^2=3.
WE ARE SIMPLY CALCULATING THE DISTANCE AT ONE POINT.
YOUR RESPONSE IS NOT CORRECT. RECONSIDER YOUR ANSWER AND TRY AGAIN...
THAT'S NOT THE ANSWER I'M LOOKING FOR. THINK ABOUT IT AND TRY AGAIN...
NO TRY AGAIN.....
12 6 1 1 2
THE LENGTH OF THE TIME INTERVAL INDICATED ON THE GRAPH IS DEL(T).
WHICH OF THE FOLLOWING REPRESENTS THE DISTANCE AT THE END OF THE
TIME INTERVAL THAT IS, AT TIME T=1+DEL(T), PLEASE ANSWER A, B, C, D, OR E.

A 3(DEL(T))*2  B 3(1+DEL(T))*2
C 3(1+DEL(T))  D 3T+2
USE THE EQUATION OF MOTION.

THE TIME AT THE END OF THE TIME INTERVAL IS T=1+DEL(T). THEN THE DISTANCE AT THIS VALUE OF TIME IS GIVEN BY
S=3T+2=3(1+DEL(T))*2
WHICH IS ALSO EQUAL TO
3+6DEL(T)+3DEL(T)*2
AS YOUR ANSWER IS INCORRECT. THINK ABOUT THE PROBLEM AND TRY AGAIN...

THINK ABOUT THE PROBLEM AGAIN AND TRY TO FIND THE RIGHT ANSWER. GO AHEAD... SEND

YOUR REPLY IS NOT CORRECT. RECONSIDER YOUR ANSWER AND TRY AGAIN...

10 8 3 3:
WE WOULD LIKE TO FIND THE AVERAGE SPEED IN THIS TIME INTERVAL FROM T=1 TO T=1+DEL(T). THE CHANGE IN DISTANCE, DEL(S), IS GIVEN BY
(DISTANCE AT END OF INTERVAL) - (DISTANCE AT START OF INTERVAL).
THEN
DEL(S) = \((3+6DEL(T)+3DEL(T)*2)-(3)*1\)
WHAT IS THE SIMPLIFIED FORM OF DEL(S)/DEL(T)?
DO SOME ALGEBRA TO SIMPLIFY THIS EXPRESSION...

DEL(T) = \((1+DEL(T))-1\)
6+3DELS 6 + 3DELS 6 + 3DELS 3(2 + DELS) 3(2 + DELS) 3DEL(T) + 683
6+3DELS 6 + 3DELS 6 + 3DELS 3(2 + DELS) 3(2 + DELS) 3DEL(T) + 683
DEL(S)/DEL(T) = \((6DEL(T)+3DEL(T)*2)/DEL(T)\)
SINCE DEL(T) CANCELS
IN BOTH NUMERATOR AND DENOMINATOR. THIS IS THE AVERAGE SPEED
IN THE INTERVAL,
/DELS DEL(T) DELS
NO, CHECK YOUR WORK AND TRY AGAIN...

3+6DELS 3 + 6S
NO, THAT IS INCORRECT... TRY AGAIN...

3+6DELS 3 + 6S
NO, CHECK YOUR WORK AND TRY AGAIN...

RECALLING THAT INSTANTANEOUS SPEED IS THE LIMIT OF AVERAGE SPEED AS THE TIME INTERVAL SHRINKS TO ZERO, THAT IS, AS DEL(T) APPROACHES ZERO.
WHAT IS THE INSTANTANEOUS SPEED AT TIME T=1 SEC.?
FIND THE LIMIT OF DEL(S)/DEL(T) AS DEL(T) APPROACHES 0.

LIMIT NO'S DONS
GOTO18
98 98 98 98 DELS
YOU SEEM TO BE UNCLEAR ABOUT WORKING OUT LIMITS. YOU SHOULD DO SOME WORK ON LIMITS FOR A FEW MINUTES BEFORE GOING ON WITH THE MAIN LESSON.
PLEASE ENTER THE WORD... LIMIT, OR TRY AGAIN IF YOU WISH.

LIMITS NO'S DONS
GOTO15
15
2 4 4
LET S=3T+7. WHEN T=2, IT IS EASY TO SEE THAT S=13. BUT HOW DOES S BEHAVE WHEN T IS CLOSE TO 27 EXamine THE TABLE GIVEN BELOW.
T 2.5 2.2 .1 2.01 2.001 2.0001
S=3T+7 14.5 14.0 13.3 13.03 13.003 13.0003
IS S CLOSE TO 13 WHEN T IS CLOSE TO 27?
DONS SEEM TO BE GETTING CLOSER TO 13 AS T GETS CLOSER TO 27? YES OR NO?
YES, ONS THINKS SURE.
WE SAY THAT IF S=3T+7, THEN S APPROACHES 13 AS T APPROACHES 2, AND WRITE
LIMIT(3T+7) AS T APPROACHES 2 IS EQUAL TO 13.

HOS DONS NO'S NO'S NO'S
GOTO15
Look at the table closely and answer again or ask for help.

6 3 3 1

The limit of S as T tends to a particular value seems to be simply the value of S at that value of T. This is generally true except only under certain conditions, which you will learn about later in your calculus course. What is the limit of S=20-6T as T approaches 3?

2. $S = 20 - 6(3) = 20 - 18$

The limit of 20-6T as T approaches 3 is 2. As we make the value of T closer and closer to 3, the value of S gets closer and closer to 2.

No. Think about it and try again...

6 $S = 6(3) = 18$

Your reply is not correct. Reconsider your answer and try again...

14$

Your response is incorrect. Try to answer again...

6 2 1 2

Find the limit of $S'/S(T) = 6 + 3S(T)$ as $S(T)$ approaches zero.

6 $S = 6 + 3(0) = 6$

The limit of $6 + 3S(T)$ as $S(T)$ approaches 0 is 6.

Wrong. Try again...

9$S = 9$

No. Think about it and try again...

18$

Let's take a short break from the lesson. I'd like to know how you feel...

Right now, which of the categories below describe best your reaction right now to the statement?

A. Not at all
B. Somewhat
C. Moderately so
D. Very much so

Please answer A, B, C, or D.

Answer A, B, C, or D to describe your reaction right now to the statement...

I am tense.

No. Yes.

Got to 19

19$

Which category below...A, B, C, or D...best describes your reaction to the statement I feel at ease.

A. Not at all
B. Somewhat
C. Moderately so
D. Very much so

Please answer A, B, C, or D.

No. Yes.

Got to 19

19$

I am relaxed.

A. Not at all
B. Somewhat
C. Moderately so
D. Very much so

Please answer A, B, C, or D.
**LET'S TRY ONE MORE TO FIND THE INSTANTANEOUS SPEED USING THE EQUATION OF MOTION, S = \( t^2 \). FIRST, WHICH OF THE FOLLOWING IS THE AVERAGE SPEED BETWEEN \( t=2 \) AND \( t=2+\Delta t \)?**

- A \((2+\Delta t)^2 - 2^2 \)/\(2+\Delta t \)  
- B \((2+\Delta t)^2 - 2^2 \)/(\(2+\Delta t \))  
- C \((2+\Delta t)^2 - 2^2 \)/(\(2+\Delta t \))  
- D \((2+\Delta t)^2 - 2^2 \)/(\(2+\Delta t \))  
- E BOTH OF THE ABOVE

Do some algebra to get \( \Delta s \) and \( \Delta t \) before finding average speed in this interval.

**THE AVERAGE SPEED IS SIMPLY \( \Delta s/\Delta t \) IN THE INTERVAL, WHICH IS GIVEN BY \((2+\Delta t)^2 - 2^2 \)/(\(2+\Delta t \)) = \(2\).**

**EITHER TYPE ...REVIEW OR ANSWER AGAIN.**

**EITHER TYPE ...REVIEW OR ANSWER AGAIN.**

---

**PLEASE ANSWER A, B, C, OR D.**

**ANSWER A, B, C, OR D TO THE STATEMENT... I AM CALM.**

- A NOT AT ALL  
- B SOMewhat  
- C MODERATELY SO  
- D VERY MUCH SO

**ANSWER A, B, C, OR D TO THE STATEMENT... I AM JITTERY.**

- A NOT AT ALL  
- B SOMewhat  
- C MODERATELY SO  
- D VERY MUCH SO

---

**WHAT IS THE INSTANTANEOUS SPEED AT \( t=2 \)?**

**REMEMBER THE RELATIONSHIP BETWEEN AVERAGE SPEED AND INSTANTANEOUS SPEED.**

**THE AVERAGE SPEED IS \((\Delta s)/\Delta t = (2+\Delta t)^2 - 2^2 / 2(2+\Delta t) = 2 \).**
SIMPLIFYING THE NUMERATOR AND DENOMINATOR GIVES
\[ \frac{\text{DEL}(S)}{\text{DEL}(T)} = \frac{\text{DEL}(T) \cdot \text{DEL}(T)}{\text{DEL}(T)} = \text{DEL}(T) \]
FROM NUMERATOR AND DENOMINATOR AND WE END UP WITH \[ \frac{\text{DEL}(T)}{\text{DEL}(T)} \]
THE LIMIT OF \[ \frac{\text{DEL}(T)}{\text{DEL}(T)} \] AS \[ \text{DEL}(T) \] TENDS TO ZERO IS \[ 1 \], WHICH IS THE INSTANTANEOUS SPEED.

\[ \text{NO. CHECK YOUR WORK AND TRY AGAIN...} \]

\[ \text{THAT'S NOT THE ANSWER I'M LOOKING FOR. THINK ABOUT IT AND TRY AGAIN...} \]

\[ \text{YOUR ANSWER IS INCORRECT. THINK ABOUT THE PROBLEM AND TRY AGAIN...} \]

\[ \text{CONGRATULATIONS! YOU HAVE COMPLETED A CAI LESSON. I HOPE THAT YOU ENJOYED OUR CONVERSATION AS MUCH AS I DID AND THAT YOU LEARNED SOMETHING NEW. DID YOU ENJOY THIS METHOD OF LEARNING?} \]

\[ \text{YES} \quad \text{OR} \quad \text{NO.} \]

\[ \text{IF YOU WISH TO MAKE ANY COMMENTS ABOUT THE LESSON, ASK THE INSTRUCTOR TO PROVIDE YOU WITH A COMMENT SHEET. GOOD-BYE FOR NOW...} \]

\[ \text{YES} \quad \text{OR} \quad \text{NO.} \]

\[ \text{PLEASE ANSWER YES OR NO.} \]
APPENDIX E

Listing for One CAI Student Session ($T_1$)
Hi. I'm your personal tutor for today. Let's start by doing a lesson on some of the things that you should know before doing the main lesson.

Look at the graph shown in Sheet A.

What is the value of y at the point x=1?

Ok.

Suppose that you are told that S is a function of T.

What is the value of S when T=3, if S and T are related by the equation S=2T², read this as ... two times (T squared).

Good.

Suppose that a car is travelling along a highway at a speed of 60 miles per hour.

How far will the car travel in 2 hours?

Excellent:

A car passes the 100 mile post on a highway at 12 noon. Three hours later, the car passes the 250 mile post. We use the symbol del(S) to record the change in distance, that is, del(S)=(final distance)-(initial distance).

What is del(S) in this case?
EXCELLENT! KEEP UP THE GOOD WORK.

SUPPOSE THAT A CAR TRAVELS FROM MONTREAL TO TORONTO, A DISTANCE OF 350 MILES, AND THE DRIVER STOPS SEVERAL TIMES FOR FOOD AND GAS. WHAT SPEED MUST THE CAR AVERAGE IN ORDER TO MAKE THE TRIP IN 7 HOURS?

50

EXCELLENT! KEEP UP THE GOOD WORK.

SUPPOSE THAT ANOTHER CAR TRAVELLING FROM MONTREAL TO TORONTO (350 MILES) MOVES AT 70 MILES/HOUR FOR THE FIRST 5 HOURS AND AT 60 M/H FOR THE NEXT 4 HOURS. WHAT IS THE SPEED OF THIS CAR EXACTLY 30 MINUTES AFTER LEAVING MONTREAL? THE SPEED AT A PARTICULAR TIME IS CALLED THE INSTANTANEOUS SPEED.

70

EXCELLENT! KEEP UP THE GOOD WORK.

LET'S TAKE A SHORT BREAK FROM THE LESSON. I'D LIKE TO KNOW HOW YOU FEEL...

RIGHT NOW. WHICH OF THE CATEGORIES BELOW DESCRIBE BEST YOUR REACTION...NOW...

TO THE STATEMENT......... I AM TENSE.

A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

c

WHICH CATEGORY BELOW... A, B, C, OR D.. BEST DESCRIBES YOUR REACTION TO THE STATEMENT.

I FEEL AT EASE.

A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

d

I AM RELAXED.

A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

d

I FEEL CALM.

A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

d

I AM JITTERY.

A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

a

NOW, LET'S GET BACK TO THE LESSON...

LOOK AT THE GRAPH OF S VS. T SHOWN IN SHEET B.

WHAT IS THE SLOPE OF THE LINE INDICATED IN THE GRAPH?

a

EXCELLENT! KEEP UP THE GOOD WORK.

LET'S REVIEW SOME BASIC ALGEBRA. SAY THAT YOU ARE GIVEN THE EXPRESSION

\[ \frac{(1+x)^2 - 3(1+x)}{(1-x)-1} \]

WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?

\[ -3x \]

NO. THE NUMERATOR BECOMES 3(1+x)^2 - 3(1+x) 2(1+2x+x^2) - 3 6x + 3x^2 + x(6\cdot 3x)

THE DENOMINATOR BECOMES (1+x)-1x

THEN, THE EXPRESSION EQUALS X(6+3x)/X=7

WHAT IS THE FINAL FORM OF THE EXPRESSION?

3(2+x)

OK
NOW YOU ARE GIVEN AN EXPRESSION \((2+X)^2-2^2 / (2+X)-2\)  
WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?  
\[ x^4 \]  
GOOD.  

LET'S DO THE SAME EXAMPLE AS BEFORE, BUT NOW WE'LL USE THE SYMBOLS THAT WILL BE USED IN THE MAIN LESSON.  
GIVEN THE EXPRESSION \(3(1+DEL(T))^2-3(1)^2 / (1+DEL(T))-1\)  
WHAT IS THE SIMPLIFIED FORM OF THIS EXPRESSION?  
\[ 3(2+DEL(T)) \]  
EXCELLENT!  

YOU SEEM TO UNDERSTAND THE CONCEPTS NEEDED TO TAKE THE MAIN LESSON.  
YOU MAY TAKE A SHORT BREAK OR YOU CAN START THE MAIN LESSON RIGHT AWAY.  DO YOU WANT TO TAKE A BREAK?  
no  
EXCELLENT! KEEP UP THE GOOD WORK.  

THEN TYPE...$SOURCE LESSON  
STOP u  
#EXECUTION TERMINATED  
#source lesson  
#$RUN CAI.O 4=DATAMAIN(LAST+1) S=T1 9=MSOURCE*  
#EXECUTION BEGINS  
PLEASE ENTER YOUR FIRST AND LAST NAME  

LET'S STUDY THE MOTION OF A BOAT AS IT LEAVES A DOCK.  
SUPPOSE THAT IT'S MOVING AT A CONSTANT SPEED OF 10 MILES/HOUR.  
WHAT IS THE DISTANCE S OF THE BOAT FROM THE DOCK AT ANY TIME T?  
\[ S=10T \]  
I DON'T RECOGNIZE YOUR RESPONSE. TRY AGAIN  
10\(t\)  
OK  

THE EQUATION WHICH DESCRIBES THE MOTION OF THE BOAT IS \( S=10T \).  
THIS IS SIMPLY THE FAMILIAR DISTANCE=\((\text{SPEED})(\text{TIME})\) EQUATION, WITH SPEED \( v \) BEING CONSTANT AT 10 MILES/HOUR.  

LOOK AT SHEET 1 THAT WAS GIVEN TO YOU. THE GRAPH INDICATES HOW FAR THIS BOAT IS FROM THE DOCK AT ANY TIME.  
WHAT IS THE SLOPE OF THIS STRAIGHT LINE REPRESENTING THE BOAT'S MOTION IN A TIME INTERVAL \( T=2 \) TO \( T=6 \) HOURS?  
10  
GOOD.  

THE SLOPE IS THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME.  
WE WRITE THIS AS \( \text{SLOPE}=(S_2-S_1)/(T_2-T_1) \) WHICH IS EQUAL TO  
\[ 10 \]  
WHAT IS THE SLOPE OF THE LINE IN THE TIME INTERVAL \( T=4 \) TO \( T=8 \) HOURS?  
10  
EXCELLENT!  


SHEET 2 ILLUSTRATES THE MOTION OF A SECOND BOAT  
COMPUTE THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL FROM \( T=2 \) TO \( T=6 \) HRS.  

EXCELLENT! KEEP UP THE GOOD WORK.

THE AVERAGE SPEED IS SIMPLY THE CHANGE IN DISTANCE DIVIDED BY THE CHANGE IN TIME. THIS IS GIVEN BY

$$V = \frac{\text{DEL}(S)}{\text{DEL}(T)} = \frac{(9-1)}{(6-2)} = \frac{8}{4} = 2 \text{ MILES/HOUR}$$

LOOK AT SHEET 3, WHICH IS JUST THE GRAPH IN SHEET 2 WITH THREE POINTS P, Q, AND R INDICATED ON IT. WHAT IS THE SLOPE OF THE LINE SEGMENT JOINING THE POINTS P AND Q?

EXCELLENT! KEEP UP THE GOOD WORK.

THE SLOPE OF THE LINE SEGMENT JOINING P AND Q IS GIVEN BY CHANGE IN DISTANCE DIVIDED BY CHANGE IN TIME, WHICH IS \(\frac{\text{DEL}(S)}{\text{DEL}(T)} = \frac{1}{4} = 2 \text{ M/HR}\). THIS IS THE SAME AS THE AVERAGE SPEED OF THE BOAT BETWEEN P AND Q.

LET'S TAKE A SMALLER SIZE INTERVAL THAN BEFORE ON THE GRAPH IN SHEET 3. WHAT IS THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL T=2 TO T=4 HOURS?

EXCELLENT! KEEP UP THE GOOD WORK.

THE AVERAGE SPEED IS $$V = \frac{\text{DEL}(S)}{\text{DEL}(T)} = \frac{(4-1)}{(4-2)} = \frac{1.5}{1.5} = 1.5 \text{ M/HR}$$.

THE SLOPE OF THE LINE SEGMENT JOINING P AND R IS AGAIN THE SAME AS THE AVERAGE SPEED OVER THIS INTERVAL.

NOTICE THAT THE AVERAGE SPEED IS NO LONGER CONSTANT!

IF THE GRAPH IS NOT A STRAIGHT LINE, THE SLOPE IS NO LONGER CONSTANT.

WHAT HAPPENS TO THE SPEED AS WE MAKE THE TIME INTERVAL SMALLER AND SMALLER, LET'S TAKE A SMALLER SIZE INTERVAL THAN BEFORE ON THE GRAPH IN SHEET 3. WHAT IS THE AVERAGE SPEED OF THE BOAT IN THE INTERVAL T=2 TO T=4 HOURS?

NO. THE LENGTH OF THE INTERVAL TENDS TO 0 BUT AVERAGE SPEED DOES NOT.

LENGTH ** 4 2 1 .5 .25 .10 0

SLOPE ** 1.5 1.25 1.12 1.06 1.02 1.00

AVERAGE SPEED ** 2 1.5 1.25 1.12 1.06 1.00

WHAT IS THE LIMIT OF AVERAGE SPEED AS THE INTERVAL SHRINKS TO SIZE 0?

THE LIMIT OF AVERAGE SPEED AS THE INTERVAL APPROACHES ZERO IS 1 M/HR.

WE SEE THAT AS THE INTERVAL KEEPS GETTING SMALLER, IT SHRINKS TO A POINT AT T=2, AS SHOWN ON SHEET 3. THE SPEED AT T=2 IS JUST THE SLOPE OF THE LINE L WHICH TOUCHES THE CURVE AT ONLY ONE POINT P. THIS LINE IS CALLED THE TANGENT TO THE CURVE AT POINT P.

WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.


WHAT IS THE INSTANTANEOUS SPEED OF THE BOAT AT THE TIME, T=2 HOURS?

GOOD.

AS TIME GETS BIGGER, DEL(S) WILL BE NEGATIVE. TRY AGAIN.

OK

THE ACTUAL SPEED AT T = 2 SEC. IS -4 FEET/SEC. THIS IS THE SLOPE OF THE LINE WHICH TOUCHES THE CURVE AT ONLY ONE POINT P. THE SLOPE IS NEGATIVE SINCE THE DISTANCE S IS GETTING SMALLER AS THE TIME T INCREASES.

THIS MEANS THAT DEL(S) WILL BE NEGATIVE.

THIS ACTUAL SPEED IS CALLED THE INSTANTANEOUS SPEED OF THE FEATHER AT T = 2 SEC. THE INSTANTANEOUS SPEED IS THE SLOPE OF THE STRAIGHT LINE WHICH TOUCHES THE CURVE IN SHEET 4 AT THE POINT P. THIS LINE IS CALLED THE TANGENT TO THE CURVE AT POINT P. DO YOU UNDERSTAND?

YES, GOOD.

THE INSTANTANEOUS SPEED IS WRITTEN AS

\[ V = \lim_{\Delta T \to 0} \frac{\Delta S}{\Delta T} \]

DS/DT IS CALLED THE DERIVATIVE OF S WITH RESPECT TO T AND REPRESENTS THE SLOPE OF A LINE TOUCHING THE CURVE AT ONLY ONE POINT.

NOW LET'S FIND THE INSTANTANEOUS SPEED BY USING THE EQUATION OF MOTION.

SHEET 5 ILLUSTRATES THE GRAPH OF THE EQUATION OF MOTION, S = 3T^2.

FIRST LOOK AT THE TIME INTERVAL BEGINNING AT T = 1 SEC.

WHAT IS THE DISTANCE S AT THE BEGINNING OF THIS TIME INTERVAL?

EXCELLENT!

THE DISTANCE S IS EASILY OBTAINED FROM THE EQUATION OF MOTION.

\[ S = 3T^2 \]

WE ARE SIMPLY CALCULATING THE DISTANCE AT ONE POINT.

THE LENGTH OF THE TIME INTERVAL INDICATED ON THE GRAPH IS DEL(T).

WHICH OF THE FOLLOWING REPRESENTS THE DISTANCE AT THE END OF THE TIME INTERVAL, THAT IS, AT TIME T = 1 + DEL(T)? PLEASE ANSWER A, B, C, D, OR E.

A 3(DEL(T))^2  B 3(1 + DEL(T))^2  C 3(1 + DEL(T))  D 3T^2  E NONE OF THE ABOVE

I DON'T RECOGNIZE YOUR RESPONSE. TRY AGAIN

OK

THE TIME AT THE END OF THE TIME INTERVAL IS T = 1 + DEL(T). THEN THE DISTANCE AT THIS VALUE OF TIME IS GIVEN BY

\[ S = 3T^2 + 3(1 + DEL(T))^2 \]

WHICH IS ALSO EQUAL TO

\[ 3 + 6DEL(T) + 3DEL(T)^2 + DEL(T)^3 \]

WE WOULD LIKE TO FIND THE AVERAGE SPEED IN THIS TIME INTERVAL FROM T = 1 TO T = 1 + DEL(T). THE CHANGE IN DISTANCE, DEL(S), IS GIVEN BY

\[ \text{(DISTANCE AT END OF INTERVAL)} - \text{(DISTANCE AT START OF INTERVAL)} \]

THEN

\[ \frac{\text{DEL(S)}}{\text{DEL(T)}} = \frac{(3 + 6DEL(T) + 3DEL(T)^2 + DEL(T)^3)}{DEL(T)^2} \]

WHAT IS THE SIMPLIFIED FORM

\[ \frac{\text{DEL(S)}}{\text{DEL(T)}} = \frac{1 + DEL(T)^2}{DEL(T)} \]

GOOD.

\[ \frac{\text{DEL(S)}}{\text{DEL(T)}} = \frac{6DEL(T) + 3DEL(T)^2 + DEL(T)^3}{6 + 3DEL(T)} \]

SINCE DEL(T) CANCELS IN BOTH NUMERATOR AND DENOMINATOR. THIS IS THE AVERAGE SPEED IN THE INTERVAL.

RECALLING THAT INSTANTANEOUS SPEED IS THE LIMIT OF AVERAGE SPEED AS THE TIME INTERVAL SHRINKS TO ZERO, THAT IS, AS DEL(T) APPROACHES ZERO.

WHAT IS THE INSTANTANEOUS SPEED AT TIME T = 1 SEC?

EXCELLENT!
LET'S TAKE A SHORT BREAK FROM THE LESSON. I'D LIKE TO KNOW HOW YOU FEEL...

RIGHT NOW, WHICH OF THE CATEGORIES BELOW DESCRIBE BEST YOUR REACTION...NOW...

TO THE STATEMENT......... I AM TENSE.
A NOT AT ALL     C MODERATELY SO
B SOMEWHAT       D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

WHICH CATEGORY BELOW... A, B, C, OR D... BEST DESCRIBES YOUR REACTION TO THE STATEMENT.

I FEEL AT EASE.
A NOT AT ALL     C MODERATELY SO
B SOMEWHAT       D VERY MUCH SO

I AM RELAXED.
A NOT AT ALL     C MODERATELY SO
B SOMEWHAT       D VERY MUCH SO

I FEEL CALM.
A NOT AT ALL     C MODERATELY SO
B SOMEWHAT       D VERY MUCH SO

I AM JITTERY.
A NOT AT ALL     C MODERATELY SO
B SOMEWHAT       D VERY MUCH SO

A

LET'S TRY ONCE MORE TO FIND THE INSTANTANEOUS SPEED USING THE EQUATION OF MOTION, S=T^2. FIRST, WHICH OF THE FOLLOWING IS THE AVERAGE SPEED BETWEEN T=2 AND T=2+DEL(T)? ANSWER A, B, C, D, OR E.

A (2+DEL(T))^2 / (2+DEL(T))^2 - 2^2  B (2+DEL(T))^2 / (2+DEL(T))^2 - 2^2  C (2+DEL(T))^2 / (2+DEL(T))^2 - 2^2  D (2+DEL(T))^2 / (2+DEL(T))^2 - 2^2  E NONE OF THE ABOVE

NO. THIS REPRESENTS DISTANCE. THE DISTANCE AT T=2 IS S=(T=2)^2 AND THE DISTANCE AT T=2+DEL(T) IS S=(T=2+DEL(T))^2. YOU MUST DIVIDE DEL(S) BY DEL(T). YOU SHOULD REPEAT THE MATERIAL DEALING WITH SHEET 5 TO BECOME CLEAR ABOUT THIS.

EITHER TYPE... REVIEW, OR ANSWER AGAIN.

NO. THE AVERAGE SPEED IS DEL(S)/DEL(T) IN THE INTERVAL.
DEL(S)=FINAL DISTANCE-INITIAL DISTANCE=(T=2+DEL(T))^2 - 2^2 AND
DEL(T)=FINAL TIME-INITIAL TIME=(T=2+DEL(T))-2.
SIMPLIFY DEL(S) AND DEL(T) AND DIVIDE THEM. YOU SHOULD REPEAT THE MATERIAL DEALING WITH SHEET 5 TO BE CLEAR ABOUT THIS. TYPE... REVIEW, OR TRY AGAIN.

NOW LET'S FIND THE INSTANTANEOUS SPEED BY USING THE EQUATION OF MOTION. SHEET 5 ILLUSTRATES THE GRAPH OF THE EQUATION OF MOTION, S=T^2.

FIRST LOOK AT THE TIME INTERVAL BEGINNING AT T=1 SEC.
WHAT IS THE DISTANCE S AT THE BEGINNING OF THIS TIME INTERVAL?

OK

THE DISTANCE S IS EASILY OBTAINED FROM THE EQUATION OF MOTION.
S=2+3=(1)^2+3.
WE ARE SIMPLY calculated THE DISTANCE AT ONE POINT.
THE LENGTH OF THE TIME INTERVAL INDICATED ON THE GRAPH IS DEL(T).
WHICH OF THE FOLLOWING REPRESENTS THE DISTANCE AT THE END OF THE TIME INTERVAL, THAT IS, AT TIME T=1+DEL(T)? PLEASE ANSWER A, B, C, D, OR E.

A 3(DEL(T))^2  B 3(1+DEL(T))^2
C 3(1+DEL(T))  D 3T+2
E NONE OF THE ABOVE

WRONG. THE DISTANCE IS GIVEN BY S=3T^2. YOU HAVE CHOSEN THE DISTANCE AT THE END OF THE INTERVAL FOR AN EQUATION OF MOTION S=3T(1+DEL(T)).

TRY AGAIN.

OK

THE TIME AT THE END OF THE TIME INTERVAL IS T=1+DEL(T). THEN THE DISTANCE AT THIS VALUE OF TIME IS GIVEN BY S=3T^2=3(1+DEL(T))^2
WHICH IS ALSO EQUAL TO 3+6DEL(T)+3DEL(T)^2

WE WOULD LIKE TO FIND THE AVERAGE SPEED IN THIS TIME INTERVAL FROM T=1 TO T=1+DEL(T). THE CHANGE IN DISTANCE, DEL(S), IS GIVEN BY

(DISTANCE AT END OF INTERVAL)-(DISTANCE AT START OF INTERVAL).
THEN DEL(S)=(3+6DEL(T)+3DEL(T)^2)-3

WHAT IS THE SIMPLIFIED FORM OF DEL(S)/(DEL(T))?

3(2+DEL(T))

GOOD.

DEL(S)/DEL(T)=(6DEL(T)+3DEL(T)^2)/DEL(T)=6+3DEL(T) SINCE DEL(T) CANCELS IN BOTH NUMERATOR AND DENOMINATOR. THIS IS THE AVERAGE SPEED IN THE INTERVAL.

RECALLING THAT INSTANTANEOUS SPEED IS THE LIMIT OF AVERAGE SPEED AS THE TIME INTERVAL SHRINKS TO ZERO, THAT IS, AS DEL(T) APPROACHES ZERO. WHAT IS THE INSTANTANEOUS SPEED AT TIME T=1 SEC?

EXCELLENT!

LET'S TAKE A SHORT BREAK FROM THE LESSON. I'D LIKE TO KNOW HOW YOU FEEL...

RIGHT NOW, WHICH OF THE CATEGORIES BELOW DESCRIBE BEST YOUR REACTION...NOW TO THE STATEMENT. ......... I AM TENSE.  
A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

PLEASE ANSWER A, B, C, OR D.

WHICH CATEGORY BEST DESCRIBES YOUR REACTION TO THE STATEMENT.

1 FEEL AT EASE. 
A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

1 AM RELAXED.
A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

1 FEEL CALM.
A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO

1 AM JITTERY. 
A NOT AT ALL  C MODERATELY SO
B SOMEWHAT  D VERY MUCH SO
ANSWER A, B, C, OR D.

LET'S TRY ONCE MORE TO FIND THE INSTANTANEOUS SPEED USING THE EQUATION OF MOTION, S= T^2. FIRST, WHICH OF THE FOLLOWING IS THE AVERAGE SPEED BETWEEN T=2 AND T=2+ DEL(T)? ANSWER A, B, C, OR E.

A  (2+DEL(T))^2  
B  (2+DEL(T))^2=2*2  
C  (2+DEL(T))^2=2*2  
D  (2+DEL(T))^2=2-DEL(T)^2  
E  NONE OF THE ABOVE

C

EXCELLENT! KEEP UP THE GOOD WORK.

THE AVERAGE SPEED IS SIMPLY DEL(S)/DEL(T) IN THE INTERVAL, WHICH IS GIVEN BY (2+DEL(T))^2=2*2 / (2+DEL(T))^2. WHAT IS THE INSTANTANEOUS SPEED AT T=2?

E

EXCELLENT! KEEP UP THE GOOD WORK.

THE AVERAGE SPEED IS DEL(S)/DEL(T)=(2+DEL(T))^2=2*2 / (2+DEL(T))^2
SIMPLIFYING THE NUMERATOR AND DENOMINATOR GIVES
DEL(S)/DEL(T)=(DEL(T)+DEL(T))^2 / DEL(T) NOW CANCEL DEL(T)
THE LIMIT OF (DEL(T) AS DEL(T) TENDS TO ZERO IS DEL, WHICH IS THE INST. SPEED

CONGRATULATIONS! YOU HAVE COMPLETED A CAI LESSON. I HOPE THAT YOU ENJOYED OUR CONVERSATION AS MUCH AS I DID AND THAT YOU LEARNED SOMETHING TOO. DID YOU ENJOY THIS METHOD OF LEARNING?

YES

EXCELLENT! KEEP UP THE GOOD WORK.

IF YOU WISH TO MAKE ANY COMMENTS ABOUT THE LESSON, ASK THE INSTRUCTOR TO PROVIDE YOU WITH A COMMENT SHEET. GOOD-BYE FOR NOW...

STOP

#EXECUTION TERMINATED

#OFF AT 14:32:39  SUN MAR 18/73

#E 60.584  $3.02
#C 20.13  $1.40
#G 15.55  $2.26
#W 46.606  $13.92
#D 2188  $26.02
#  $252.66
APPENDIX F

Posttest
FINAL TEST

INSTRUCTIONS: Please answer all questions. Enter your choice in the space provided on the answer sheet.

Use the scrap paper provided for your calculations.
1. What is the name for the slope of a straight line segment joining two points on the graph of distance vs. time?

   a. tangent  
   b. derivative  
   c. average speed  
   d. speed  
   e. instantaneous speed

2. What is the name for the slope of a straight line segment which is tangent to the curve of distance vs. time?

   a. average speed  
   b. instantaneous speed  
   c. tangent  
   d. change  
   e. speed

3. What is the name for the limit of average speed in an interval as the size of that interval approaches zero?

   a. derivative  
   b. average speed  
   c. instantaneous speed  
   d. tangent  
   e. speed

4. What is the name for the slope of a straight line segment which is tangent to the curve of $S$ vs. $T$ and is written as $DS/DT$?

   a. derivative  
   b. slope  
   c. tangent  
   d. change  
   e. speed
5. Refer to the graph in figure 1. Calculate the average speed in the interval between $T = 5$ and $T = 20$ hours.

a 0.5  
b 15  
c 20  
d 2  
e 1
6. Refer to the graph shown in Figure 2. Compute the average speed in the interval from $T = 1$ to $T = 3$ hours.

   a  0.2  
   b  1.0  
   c  3.3  
   d  4.0  
   e  4.5  

7. Refer to the graph shown in Figure 2. Compute the instantaneous speed at $T = 2$ hours.

   a  1  
   b  2  
   c  3  
   d  4  
   e  5  

8. Refer to the graph shown in Figure 2. Compute the derivative of distance with respect to time, that is $DS/DT$ at the point $T = 2$

   a  1  
   b  2  
   c  3  
   d  4  
   e  5
9. What is the value of the expression given below?

\[
\text{LIMIT OF } (3T+4\text{DEL}(T)-6) \text{ AS DEL}(T) \text{ TENDS TO } 0.
\]

a 3T  
b 3T+4  
c 3T-6  
d -6  
e 3

10. What is the value of the expression given below?

\[
\text{LIMIT OF } (4T\text{DEL}(T)*2+\text{DEL}(T)+5) \text{ AS DEL}(T) \text{ TENDS TO } 0.
\]

a 5  
b 4  
c 2  
d 4T  
e 4T+5

11. Define the instantaneous speed V, at any time T, as a function of distance S(T) and time T(T).

a V = S/T  
b V = DEL(S)/DEL(T)  
c V = \text{LIMIT} (S/T) \text{ AS } T \text{ TENDS TO } 0.  
d V = \text{LIMIT} (\text{DEL}(S)/\text{DEL}(T)) \text{ AS } \text{DEL}(T) \text{ TENDS TO } 0.  
e V = \text{LIMIT} (S/T) \text{ AS } \text{DEL}(T) \text{ TENDS TO } 0.

12. Given that S = 2T represents the distance S of a boat at any time T, compute the average speed of the boat between T = 1 and T = 1+DEL(T).

a 0  
b 2  
c 4  
d 6  
e 8

13. For the boat in problem 12, compute the instantaneous speed at T=3.

a 0  
b 2  
c 3  
d 6  
e 8
14. Given that $S = T^2 + 8$ represents the distance $S$ of a boat at any time $T$, compute the average speed of the boat between $T=1$ and $T=1+\Delta T$.

a. $(1+\Delta T)^2 + 8$  
b. $(1+\Delta T)^2 - 1$  
c. $\frac{(1+\Delta T)^2 - 1}{\Delta T}$  
d. $\frac{(1+\Delta T)^2 + 8}{\Delta T}$  
e. $\frac{(1+\Delta T)^2 - 1}{\Delta T}$

15. For the boat in problem 14, compute the instantaneous speed at $T = 1$.

a. $(1+\Delta T)^2$  
b. $2 + \Delta T$  
c. 8  
d. 1  
e. 2

16. Given an equation $S = 6T$, calculate the derivative of $S$ with respect to $T$, $DS/DT$, at the point $T = 2$.

a. 0  
b. 2  
c. 6  
d. 12  
e. 36

17. Given an equation $S = T^2$, calculate $\Delta L(S)/\Delta L(T)$.

a. $2T$  
b. $(T+\Delta T)^2$  
c. $T + \Delta T$  
d. $2T + \Delta T$  
e. $\Delta L(T)^2$
18. Given an equation $S = T^2$, calculate the derivative of $S$ with respect to $T$, $DS/DT$, at the point $T = 4$, using the limit definition.

a) $2T$
b) $T^2$
c) 2
d) 4
e) 8
NAME:  

ANSWER SHEET

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KEY

1. C
2. B
3. C
4. A
5. D
6. E
7. D
8. D
9. C
10. A
11. D
12. B
13. B
14. C
15. E
16. C
17. D
18. E
APPENDIX G

State-Trait Anxiety Inventory
SELF-EVALUATION QUESTIONNAIRE
Developed by C. D. Spielberger, R. L. Gorsuch and R. Lushene
STAI FORM X-1

NAME ______________________ DATE __________________

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1. I feel calm © © © ©
2. I feel secure © © © ©
3. I am tense © © © ©
4. I am regretful © © © ©
5. I feel at ease © © © ©
6. I feel upset © © © ©
7. I am presently worrying over possible misfortunes © © © ©
8. I feel rested © © © ©
9. I feel anxious © © © ©
10. I feel comfortable © © © ©
11. I feel self-confident © © © ©
12. I feel nervous © © © ©
13. I am jittery © © © ©
14. I feel “high strung” © © © ©
15. I am relaxed © © © ©
16. I feel content © © © ©
17. I am worried © © © ©
18. I feel over-excited and rattled © © © ©
19. I feel joyful © © © ©
20. I feel pleasant © © © ©

CONSULTING PSYCHOLOGISTS PRESS
577 College Avenue, Palo Alto, California 94306
SELF-EVALUATION QUESTIONNAIRE
STAI FORM X-2

NAME ___________________________________________ DATE ________________

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

21. I feel pleasant ................................................................. 0 1 2 3 4
22. I tire quickly ..................................................................... 0 1 2 3 4
23. I feel like crying ................................................................ 0 1 2 3 4
24. I wish I could be as happy as others seem to be ............... 0 1 2 3 4
25. I am losing out on things because I can’t make up my mind soon enough .... 0 1 2 3 4
26. I feel rested ....................................................................... 0 1 2 3 4
27. I am “calm, cool, and collected” ........................................ 0 1 2 3 4
28. I feel that difficulties are piling up so that I cannot overcome them .......... 0 1 2 3 4
29. I worry too much over something that really doesn’t matter .......... 0 1 2 3 4
30. I am happy ........................................................................ 0 1 2 3 4
31. I am inclined to take things hard ......................................... 0 1 2 3 4
32. I lack self-confidence .......................................................... 0 1 2 3 4
33. I feel secure ...................................................................... 0 1 2 3 4
34. I try to avoid facing a crisis or difficulty ............................. 0 1 2 3 4
35. I feel blue ........................................................................... 0 1 2 3 4
36. I am content ...................................................................... 0 1 2 3 4
37. Some unimportant thought runs through my mind and bothers me .......... 0 1 2 3 4
38. I take disappointments so keenly that I can’t put them out of my mind .... 0 1 2 3 4
39. I am a steady person ........................................................... 0 1 2 3 4
40. I become tense and upset when I think about my present concerns .......... 0 1 2 3 4

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APPENDIX H

Tables of Correlation Coefficients
### Table 17: Intercorrelation Matrix for Combined Groups

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<td>6. Do you understand? - Main Lesson</td>
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<td>21. A-State - Main Lesson</td>
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* | \( r > .25 \) is significant at the \( \alpha = .05 \) level.
## Table 18

**Comparison of Selected Correlation Coefficients for T₁, T₂, T₃**

<table>
<thead>
<tr>
<th>Correlation Between Variables</th>
<th>Pooled</th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
<th>χ²&lt;sub&gt;obs&lt;/sub&gt;</th>
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<tbody>
<tr>
<td>Posttest and Proportion of Errors</td>
<td>-.42</td>
<td>-.48</td>
<td>-.50</td>
<td>-.03</td>
<td>3.87</td>
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<td>Posttest and Total Correct-main</td>
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<td>.64</td>
<td>.56</td>
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<td>.30</td>
<td>.09</td>
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<td>-.40</td>
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<tr>
<td>Proportion of Errors and A-State</td>
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<td>.32</td>
<td>.33</td>
<td>.36</td>
<td>.03</td>
</tr>
<tr>
<td>Prelesson Score and Response to &quot;Do you understand?&quot;</td>
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<td>.12</td>
<td>.62</td>
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<td>4.11</td>
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<td>.41</td>
<td>.41</td>
<td>.62</td>
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<td>-.45</td>
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<td>.09</td>
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<td>* 1.13</td>
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</table>

* χ²<sub>obs</sub> > χ²(2) = 5.99 is significant at the η = .05 level.

This value was calculated using a Fortran computer program written by the author.